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User's Manual for EXPLORE-I A River Basin Water Quality Appendix B

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APPENDIX B
USER'S MANUAL
FOR
EXPLORE-I: A RIVER BASIN
WATER QUALITY MODEL

by

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EXPLORE-I, the Battelle-Northwest water quality model, is a computer program which simulates the dynamic hydraulic and water quality characteristics of a river basin. It can be used to study the effects of various flow conditions, waste discharge and treatment schemes on the water quality levels of lakes, reservoirs, streams, and rivers. This User's Manual provides the information needed for setting up and analyzing a river basin. Descriptions of the models and their use are also provided.

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SUMMARY

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APPENDIX B

USER'S MANUAL

INTRODUCTION

The Battelle Northwest (BNW) water quality model, EXPLORE-I, is a computer program which simulates the dynamic hydraulic and water quality characteristics in a river basin. It can be used to study the effects of various flow conditions, waste discharge and/or treatment schemes on the water quality levels in the river basin.

EXPLORE-I is capable of simulating a number of hydraulic regimes in either a dynamic or steady state mode. These are:

- streams and rivers,
- shallow lakes,
- estuaries or tidally influenced rivers, and
- thermally stratified reservoirs.

In addition, the behavior of the following water quality parameters can be studied:

- Carbonaceous Biochemical Oxygen Demand (BOD)
- Nitrogenous BOD
- Benthic BOD
- Total Organic Carbon (TOC)
- Refractory Organic Carbon
- Sedimentary Phosphorus
- Soluble Phosphorus
- Organic Phosphorus
- Ammonia Nitrogen
- Nitrite Nitrogen
- Nitrate Nitrogen
- Organic Nitrogen

- Toxic Compounds
- Phytoplankton
- Zooplankton
- Dissolved Oxygen

This user's manual is intended to provide the information necessary to set up and analyze a river basin. Summary descriptions of the models used are provided to assist in understanding the code and selecting the necessary input values. A more complete discussion of the models is given in the main portion of this report. The programming details of the code are described in Appendix C, Programmer's Manual with program listings.

GENERAL DESCRIPTION OF EXPLORE-I

The EXPLORE-I computer model consists of four computer program modules:

- hydraulic code for river and estuarine flow,
- quality code for river and estuary systems,
- hydrothermal code for thermally stratified reservoirs, and
- quality code for thermally stratified reservoirs.

The hydraulic and hydrothermal codes must be run first to provide flow and/or temperature patterns which are input information for the quality codes. The river basin codes are not coupled to the deep reservoir models, so quality profiles in impoundments must be analyzed separately.

EXPLORE-I River Basin Codes

As explained above, the EXPLORE-I river basin model consists of a hydraulic code and a quality code. The hydraulic code, which is executed first, produces a magnetic tape which contains all the necessary geometric and hydraulic data used by the quality code. This separation of hydraulic and quality calculations allows the user to set up and calibrate the hydraulic model while gathering data for the quality model.

Each of these codes has two parts, an input program and a calculation program. The results of the input programs are stored on magnetic tape for use by the calculational code. The input codes check the input data deck for consistency and calculate all time varying functions needed by the calculational codes. This allows the user to check his input before executing the calculational portion of the code. A diagram of the river basin code is shown in Figure B-1.

The hydraulic and quality codes are set up to operate for a specified number of cycles; each calculation begins with a specific cycle and ends with a specific cycle. These are normally referred to as tidal cycles. However, the user can specify a cycle different from the tidal cycle (for example, a daily cycle) if no tidal influence occurs in the river basin being modeled. The quality code will accept two types of hydraulic input:

(1) time varying hydraulic data which in general is not cyclic in nature; and

(2) steady or cyclic varying flows.

If the user wanted to observe the effects of increased flow from an upstream source or from time varying additions and withdrawals of water from the system, option (1) would be used since these actions are not cyclic in nature. If only constant or cyclic flows (such as tidally influenced flows) were of interest, option (2) would be used. With option (2) the quality code will use the hydraulic data for one cycle again and again as it calculates the quality parameter concentrations for a number of cycles.

Since it is difficult to input all the initial velocities, depths, and flows exactly, both options allow the hydraulic code to calculate for a specified number of cycles before writing out the results of the calculations or starting to add time varying inputs. The time variables used in the hydraulic and quality codes are discussed below.

The relationship between the time bases used in the hydraulic and quality codes is most simply illustrated by time lines, as shown in Figure D-2. The variables in this figure are defined as:

- Hydraulic code time variables

NQSWRT = the number of the tidal cycle where printout and writing of time varying hydraulic data begin. NQSWRT refers to a segment of time rather than to a specific point in time; it is the number of the tidal cycle at which the system establishes the proper initial conditions.

NTCYC = the number of the last tidal cycle for which the hydraulic calculations will be performed. NTCYC also refers to a time segment rather than to a specific point in time.

OVERVIEW OF THE BNW EXPLORE-I RIVER BASIN CODES

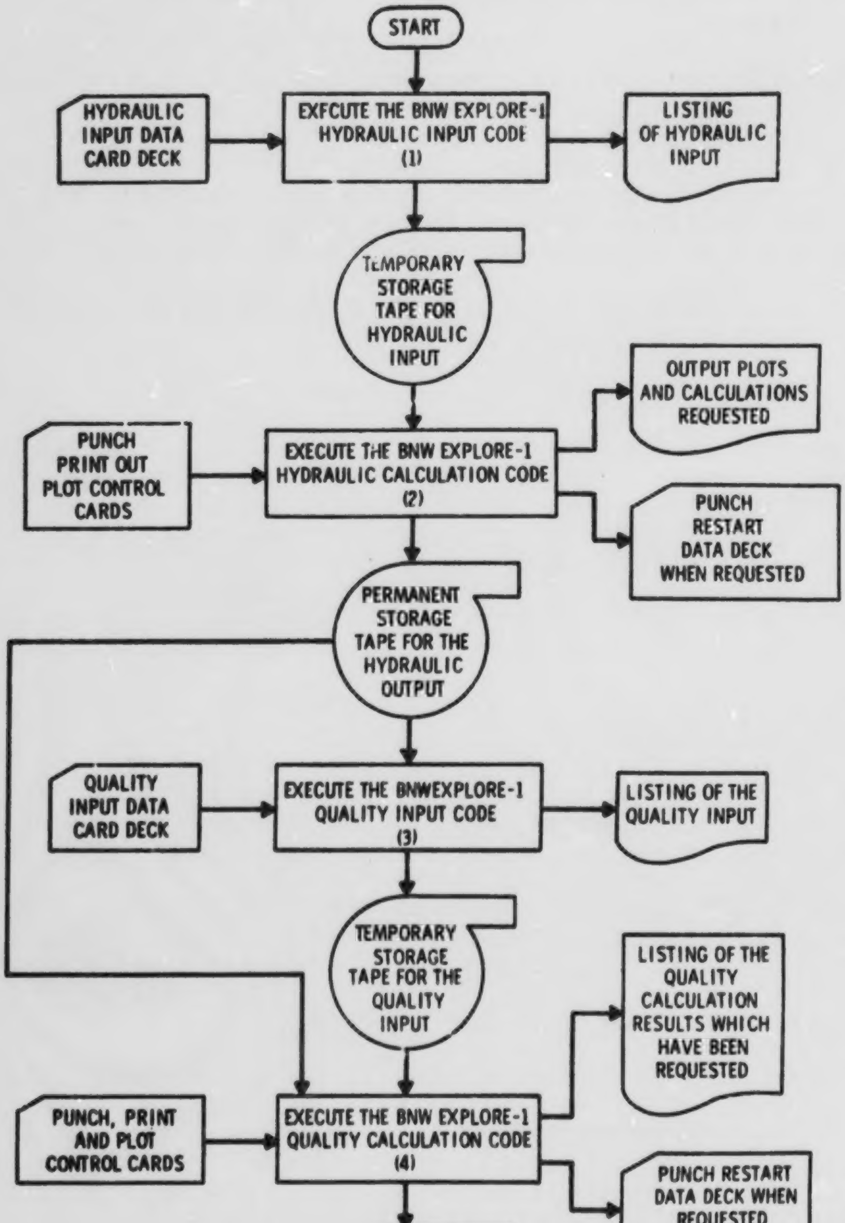
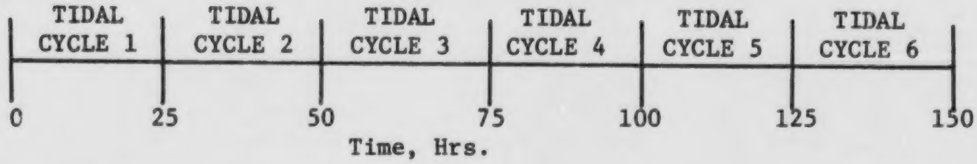

START
HYDRAULIC INPUT DATA CARD DECK
EXECUTE THE BNW EXPLORE-1 HYDRAULIC INPUT CODE (1)
LISTING OF HYDRAULIC INPUT
TEMPORARY STORAGE TAPE FOR HYDRAULIC INPUT
OUTPUT PLOTS AND CALCULATIONS REQUESTED
PUNCH PRINT OUT PLOT CONTROL CARDS
EXECUTE THE BNW EXPLORE-1 HYDRAULIC CALCULATION CODE (2)
PUNCH RESTART DATA DECK WHEN REQUESTED
PERMANENT STORAGE TAPE FOR THE HYDRAULIC OUTPUT
QUALITY INPUT DATA CARD DECK
EXECUTE THE BNWEXPLORE-1 QUALITY INPUT CODE (3)
LISTING OF THE QUALITY INPUT
TEMPORARY STORAGE TAPE FOR THE QUALITY INPUT
LISTING OF THE QUALITY CALCULATION RESULTS WHICH HAVE BEEN REQUESTED
PUNCH, PRINT AND PLOT CONTROL CARDS
EXECUTE THE BNW EXPLORE-1 QUALITY CALCULATION CODE (4)
PUNCH RESTART DATA DECK WHEN REQUESTED
PERMANENT STORAGE TAPE FOR THE QUALITY OUTPUT

FIGURE B-2. RELATIONSHIP OF TIME BASE IN HYDRAULIC AND QUALITY CODES

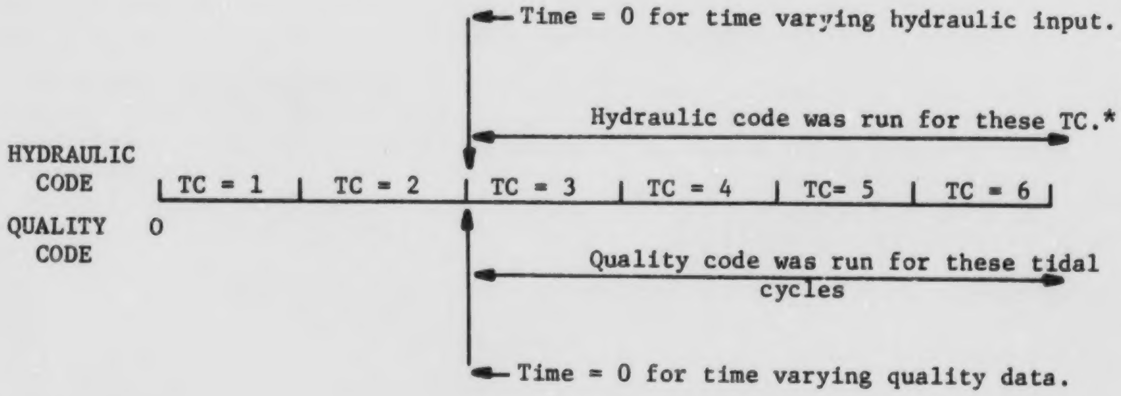
A. Time line

Tidal Cycles with PERIOD = 25 hrs.


TIDAL CYCLE 1
TIDAL CYCLE 2
TIDAL CYCLE 3
TIDAL CYCLE 4
TIDAL CYCLE 5
TIDAL CYCLE 6
0
25
50
75
100
125
150
Time, Hrs.

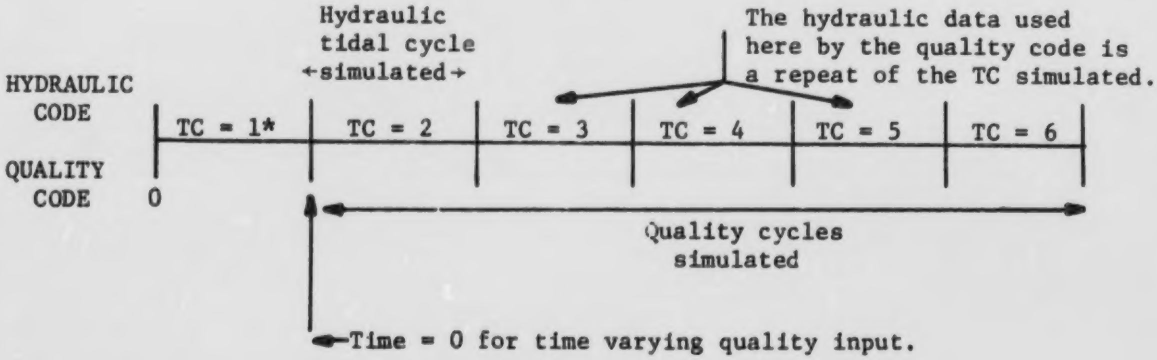
B. Time line showing NQSWRT, NTCYC, NTQCYC and zero time for the hydraulic time varying data and for the quality time varying data

(For example let NQSWRT = 3, NTCYC = 6, NTQCYC = 6, PERIOD = 25)


Time = 0 for time varying hydraulic input.
Hydraulic code was run for these TC.*
HYDRAULIC CODE
TC = 1
TC = 2
TC = 3
TC = 4
TC= 5
TC = 6
QUALITY CODE
0
Quality code was run for these tidal cycles
Time = 0 for time varying quality data.

C. Time line showing NQSWRT, NTCYC, NTQCYC and zero time point for steady state or cyclic hydraulic data

(For example let NQSWRT = 2, NTCYC = 2, NTQCYC = 6, PERIOD = 25)


Hydraulic tidal cycle ←simulated→
The hydraulic data used here by the quality code is a repeat of the TC simulated.
HYDRAULIC CODE
TC = 1*
TC = 2
TC = 3
TC = 4
TC = 5
TC = 6
QUALITY CODE
0
Quality cycles simulated
Time = 0 for time varying quality input.

*TC = Tidal cycle

PERIOD = Period of one tidal cycle in hours.

- Quality code time variable

NTQCYC = The number of the last tidal cycle for which the quality model will be run. The quality model will be run for the tidal cycle number starting with NQSWRT and ending with NTQCYC.

For the purposes of diurnal calculations the quality code assumes that the start of the time varying data is midnight.

HYDRAULIC CODE

The hydraulic model was originally developed for the receiving water block of the Storm Water Management Model (SWMM) by Water Resource Engineers (WRE). Because the SWMM hydraulic model has been previously applied successfully to various problems[B-1,B-2,B-3], it was chosen for this study. An extensive discussion of the theory appears in Reference B-3 and will not be given here.

The SWMM hydraulic code solves two-dimensional problems with one-dimensional equations by requiring the two-dimensional system to be described by a set of interconnected "channels" and "junctions" which represent the actual physical system. The equations of motion and continuity for a one-dimensional hydraulic system consist of two simultaneous equations referred to as the Saint Venant equations. These equations can be written in terms of the discharge, rather than velocity, as the primary kinetic variable. For flow through a channel of rectangular cross section, these equations are:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + g\frac{\partial h}{\partial x} - gS_o + gS_f - gS_w = 0 \qquad \text{(B-1)}$$

and

$$b\frac{\partial h}{\partial t} + \frac{\partial q}{\partial x} = 0 \qquad \text{(B-2)}$$

where

h = water surface elevation

u = vertically averaged velocity

b = channel width

q = discharge

S_o = bottom slope

S_f = bottom friction

S_w = wind stress

The SWMM code uses a modified set of one-dimensional Saint Venant equations to model the two-dimensional flow in an estuary or river basin by superimposing on the estuary or river basin a grid of junctions and channels. Only one-dimensional flow is then allowed in the channels connecting the junctions. Each junction in the system is a water and potential energy storage element which is characterized by its (1) surface area, (2) water surface elevation, (3) bottom elevation, and (4) the actual (X,Y) coordinates of the junction points. The water storage of the basin or estuary is represented by this series of junctions. Flow between these junctions is through rectangular channels which connect the junctions. A channel is described by its (1) length, (2) width, (3) Manning coefficient, (4) average bottom elevation at the midpoint, and (5) the junction numbers which lie at its end points.

The two Saint Venant equations are not solved simultaneously for this system. Instead, the one-dimensional equation of motion, Equation B-1, is solved for each of the channels in the system on the basis of the present values of the junction heads. Velocity and flow in each of the channels are thus determined. Next, the modified equation of continuity, Equation B-3:

$$A_{sj} \frac{\partial H_j}{\partial t} = \sum_{i=1}^{k} Q_i + Q_j^{im} + Q_j^{ex} - Q_j^{ev} \tag{B-3}$$

where

A_{sj} = surface area associated with the junction j

Q_i = flow of a connecting channel

Q_j^{im} = water importation rate to the junction

Q_j^{ex} = water exportation rate from the junction

Q_j^{ev} = evaporation rate

is solved for each of the junctions on the basis of the predicted flows in each of the channels. This process is repeated for the duration of the simulated time period.

Hydraulic Data Input Information

An example of the nodalization of a river basin is shown in Figure B-3. The selection of junctions and channel locations and the necessary data for each is discussed below.

Junction Data. The selection of junction points and the distances between them are determined by the size time step desired for running the hydraulic model. For a large problem a time step greater than 100 seconds would generally be used. For most estuaries and large rivers (flows greater than a few thousand cfs), the maximum time step, Δt, which can be used for a given channel length, L, is determined approximately from

$$\Delta t \leq \frac{L}{\sqrt{gR}} \qquad \text{(B-4)}$$

where

R = the hydraulic radius ($R \doteq$ average water depth) of the channel

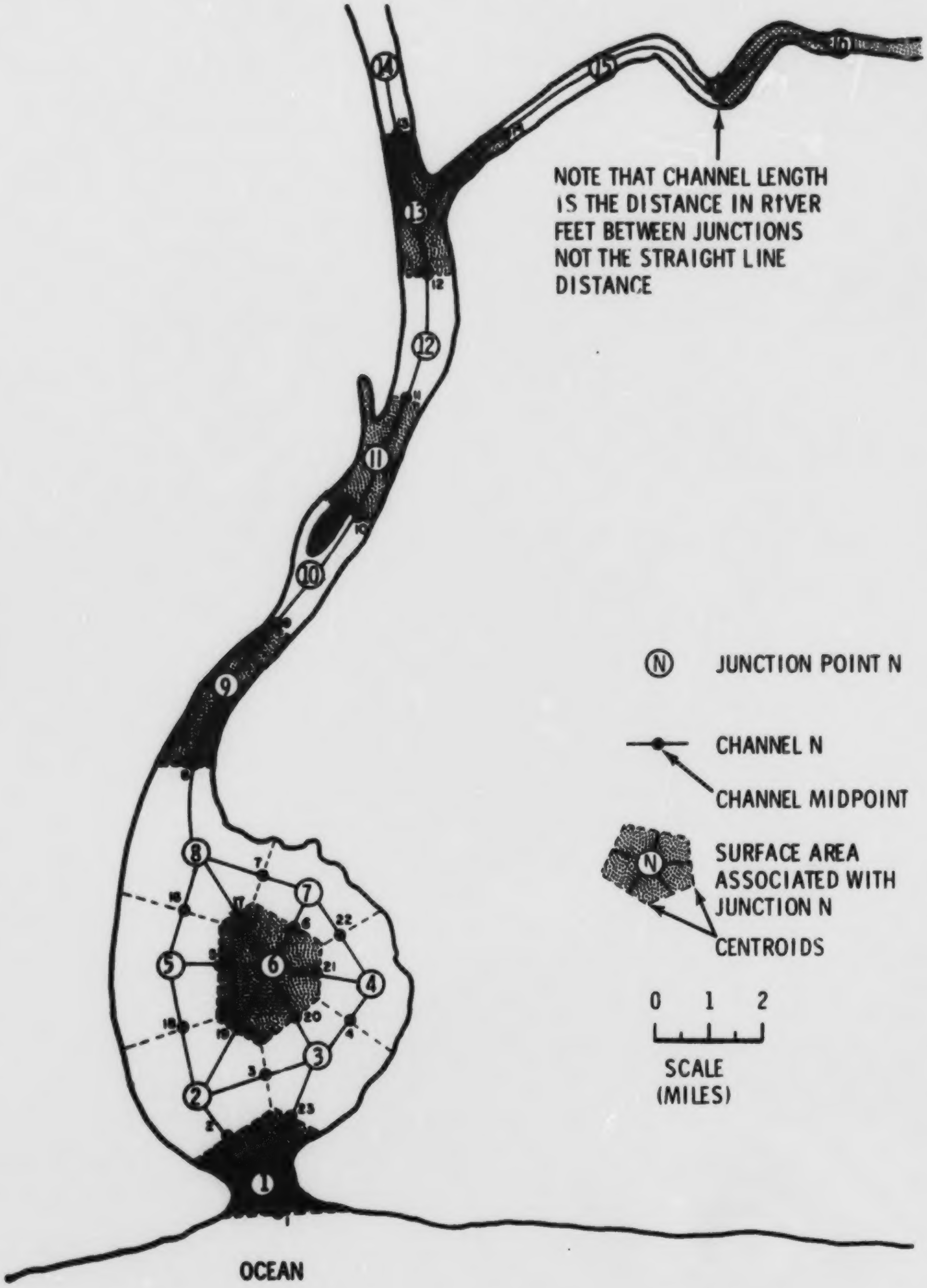
L = length

g = gravitational constant

Figure B-3 shows the initial nodalization of a sample river basin. After running the model, the user might wish to add new junctions, change the locations of junctions, or remove junctions if some channels are too short and are causing numerical instabilities.

Figure B-4 is a worksheet which can be used to gather the data necessary to describe the junctions. As indicated on the worksheet, and described in succeeding paragraphs, physical data are required for:

1) the average water surface elevation for the junction point,
2) the water surface area associated with the junction point,
3) any significant inflows to the junction point from small streams, tributaries or other sources,
4) any significant outflows from the junction point,
5) the average elevation of the bottom of the river or estuary for the junction point, and
6) the cartesian coordinates of the junction point (necessary only if the effect of wind stress on channel flow is being


14
16
15
13
12
11
10
9
8
7
6
5
4
3
2
1
OCEAN
(N) JUNCTION POINT N
CHANNEL N
CHANNEL MIDPOINT
SURFACE AREA ASSOCIATED WITH JUNCTION N
CENTROIDS
0 1 2
SCALE (MILES)

NOTE THAT CHANNEL LENGTH IS THE DISTANCE IN RIVER FEET BETWEEN JUNCTIONS NOT THE STRAIGHT LINE DISTANCE

FIGURE B-3. A SAMPLE RIVER BASIN

FIGURE B-4. WORKSHEET FOR GATHERING INPUT DATA TO DESCRIBE THE PROBLEM'S JUNCTION POINTS

JUNCTION DATA
RIVER(OR STREAM) ______________________

COLUMNS

		1-5	6-15	16-25	26-35	36-45	46-55	61-70	71-80
RIVER MILE	INPUT SOURCE	NODE NUMBER	HEAD (FT)	SURFACE AREA (MILLIONS OF SQ FT)	INFLOW (CFS)	OUTFLOW (CFS)	CHANNEL BOTTOM ELEVATION (FT)	X THOUSANDS OF FEET	Y THOUSANDS OF FEET

calculated).

The water surface elevations need only be a reasonable guess, as the code will predict the correct head after the simulation has run a day or two. The initial head can be determined from the elevation (taken from topographic maps), by adding the known water depth at the junction point to the known elevation of the river or estuary bottom, or from other sources (e.g., Corps of Engineers records, if available).

The surface area of a junction is bounded by the lines which connect the centroids of adjacent areas. Figure B-3 illustrates the method of determining the surface area of a junction for almost any kind of junction point. The surface area can be obtained by planimetering topographic or navigation maps. Junctions with tributary inflows which are not modeled should be accounted for by a representative surface area.

Inflow rates for tributaries or streams which are not modeled but contribute a significant amount of water into the junction should be specified. Outflow rates for unmodeled outflows should also be specified.

The average elevation of the river or estuary bottom for the junction point can be determined from

- physical measurements;
- navigation charts or topographic maps which give sounding contours for the river or estuary (any good method of averaging this data can be used to determine the average junction point's bottom elevation; see Reference B-3 for one method); and
- data (such as from the U. S. Corps of Engineers) available on average water depth versus river mile (the area under this curve can be integrated and divided by the channel length to determine the average water depth for the junction).

The cartesian coordinate system used to define the (X,Y) values must be a right-hand coordinate system, i.e., the positive Y axis must point north.

Channel Data. Figure B-5 is a worksheet which can be used to gather the data necessary to describe the channels. As indicated by the channel worksheet and described below, physical data must be gathered for:

1) channel length,

FIGURE B-5. WORKSHEET FOR GATHERING INPUT DATA TO DESCRIBE THE PROBLEM'S CHANNELS

CHANNEL DATA
RIVER(OR STREAM) ____________________

COLUMNS

1-5	6-10	11-15	26-35	36-45	46-55	56-65	66-75
CHANNEL NUMBER	JUNCTION AT LOWER END OF CHANNEL	JUNCTION AT UPPER END OF CHANNEL	LENGTH OF CHANNEL (FT)	WIDTH OF CHANNEL (FT)	AVERAGE RIVER DEPTH (FT)	MANNING COEFFICIENT	INITIAL VELOCITY (FT/SEC)

2) channel width,

3) average elevation of the channel bottom,

4) Manning coefficient for the channel, and

5) initial velocity in the channel.

The length of a channel is simply the distance in river feet between the two junction points which lie at either end of the channel (see Figure B-3).

The channel width is the average surface width of a river or tributary channel or the distance between centroids of adjacent areas for an estuary channel (see Figure B-3).

The average elevation of the channel bottom can be estimated as the average of the bottom elevations of the junctions at the ends of the channel.

If actual measurements are not available, the Manning friction coefficient for the channel can be estimated from Table B-1 below.

TABLE B-1

A TABULATION OF VALUES OF THE MANNING FRICTION COEFFICIENT FOR VARIOUS TYPES OF RIVER CHANNELS[B-4]

Natural River Channels	
Clean and straight	0.025-0.030
Winding, with pools and shoals	0.033-0.040
Very weedy, winding, and overgrown	0.075-0.150

The initial velocity must be supplied only for channels where a stability problem might exist. Flow and velocity in the channels are positive when the flow in the channel is from a low junction number to a high junction number. In an estuary or large river where the channels are more likely to be stable, 0 can be input for the initial velocity.

Controlled Nodes and Upstream Boundary Conditions. The solution of the hydraulic problem requires two driving functions:

- an upstream constant or time varying flow input for the upstream end point junctions, and

- a time varying function to control the head or outflow for the downstream end point junctions (controlled nodes).

For the sample river system in Figure B-3, constant or time varying inflows would be specified for upstream junctions 14 and 16 and a stage versus time history would be supplied for the downstream controlled node 1.

Constant inflows to upstream end point junctions are simply specified as inflows on the junction data sheets (see Figure B-4). Time varying upstream inputs are handled as indicated below.

Controlled nodes, which are required at every downstream boundary in the river system, specify the boundary conditions. When simulating an entire river basin it is likely that points of discontinuity such as dams, waterfalls and locks will occur in the hydraulic system. These are not downstream end points but they must be controlled as if they were. The previous structure of the SWMM code would have required simulation of each portion of the river basin lying between two discontinuities as a separate problem. The modified code nodalizes the entire river basin to include these discontinuities and locates a controlled junction at each point where flow or head is to be specified. An associated controlled channel must connect this controlled junction with the next downstream junction.

Use of the controlled nodes and channels must conform to the following rules:

- Controlled junctions must be numbered first; for instance, if there are N controlled junctions in the system they must be numbered as junctions 1 through N.
- Each controlled junction (except a tidally influenced one) must have only downstream flow.
- Each controlled junction must have only one controlled channel connecting it downstream to another junction (or seaward, with no junction, in the case of a tidally influenced junction).
- No two controlled nodes can be directly connected by a channel.

Except for these restrictions, numbering of nodes and channels can be carried out in any order.

Six types of controlled nodes are allowed. They are:

1) a weir type, in which the flow over the weir and out of the controlled node is determined by the formula

$$Q = A_1(H-A_2)^{A_3} \qquad \text{(B-5)}$$

where

Q = flow, cfs

H = water surface elevation upstream of weir, ft

A_1 = weir coefficient, cfs

A_2 = elevation of weir, ft

A_3 = weir exponent

2) a tidally controlled node at which the stage versus time history is specified;

3) a Q versus H dam, where outflow is controlled as a function of the dam upstream water surface elevations [the user inputs an array of (H,Q) points which are fit by polynomial regression to form a function to predict Q for any value of H];

4) a dam at which head and outflow are both known functions of time [the user supplies an array of (t,Q) points and an array of (t,H) points; these arrays are fit by polynomial regression and two time functions are formed, one to predict Q as a function of time and one to predict H as a function of time];

5) a dam at which head is a known function of time [the outflow from the dam is determined via a mass balance; an array of (t,H) points is supplied by the user and a polynomial function is fit to these data points]; and

6) a dam at which outflow is a known function of time and head must be determined from a mass balance [an array of (t,Q) points is supplied and a polynomial fit of the data is performed].

Time Varying Inflows or Upstream Hydraulic Inputs from Flow Hydrographs. The user can specify time varying inflows to any junction in the system by indicating the number of time varying inputs and an array of junction numbers where these inputs are to be added. In addition, the user must supply an array of (Flow,t) points for each input. These arrays are then fit via polynomial regression and functions are formed so that the inflow or outflow can be predicted for any time.

Evaporation and Wind Stress. If in the river basin being simulated evaporation or wind can significantly affect flow patterns or water quality, the gross effects of these factors can be accounted for. The user can supply an evaporation rate in (inches/month) and the average wind speed and direction for the entire basin.

Tributary Channels. The original SWMM hydraulic code had to be modified to allow the marking of "small tributary channels" which became necessary at every junction between a large river and a small tributary. The WRE code calculates the hydraulic radius of a channel by averaging the characteristics of the nodes at the ends of the channel. In a single river or an embayment all of the channels have similar characteristics and this is a valid estimation. However, at the junction between a large river and a small side tributary the characteristics of the small tributary channel are grossly overestimated by averaging the properties of the nodes at the channel ends. The properties of the channel are most like those of the first upstream node in the tributary (except when backflow up the tributary is allowed). The changes in the hydraulic code allow the user to mark the small tributary channels and associate with each of these channels the characteristics of the first upstream node in the small tributary. The revised code then simply calculates the channel properties for the small tributary channel on the basis of the properties of the marked upstream node. If there is backflow up the tributary channel properties are calculated in the normal manner.

Hydraulic Input Data Deck Preparation

After the river-estuary system has been nodalized as described above, the data sheets for the junctions and channels have been prepared, and data has been gathered on controlled nodes, time varying input, evaporation rates, and wind speed and direction, the input data deck is prepared. Table B-2 indicates the card format and the relative order of the input card deck. Figure B-6 shows the proper deck structure for running the BNW EXPLORE-I hydraulic input code. Figure B-7 is an annotated listing of the data cards described in Table B-2. This data deck was used for calibration of the computer code on the Willamette River Basin from Salem to Portland, Oregon. The results of these calibration runs are discussed in detail in the main report. A stick diagram of the physical layout of the Willamette River Basin is given in Figure B-8 to make the data card listings more meaningful.

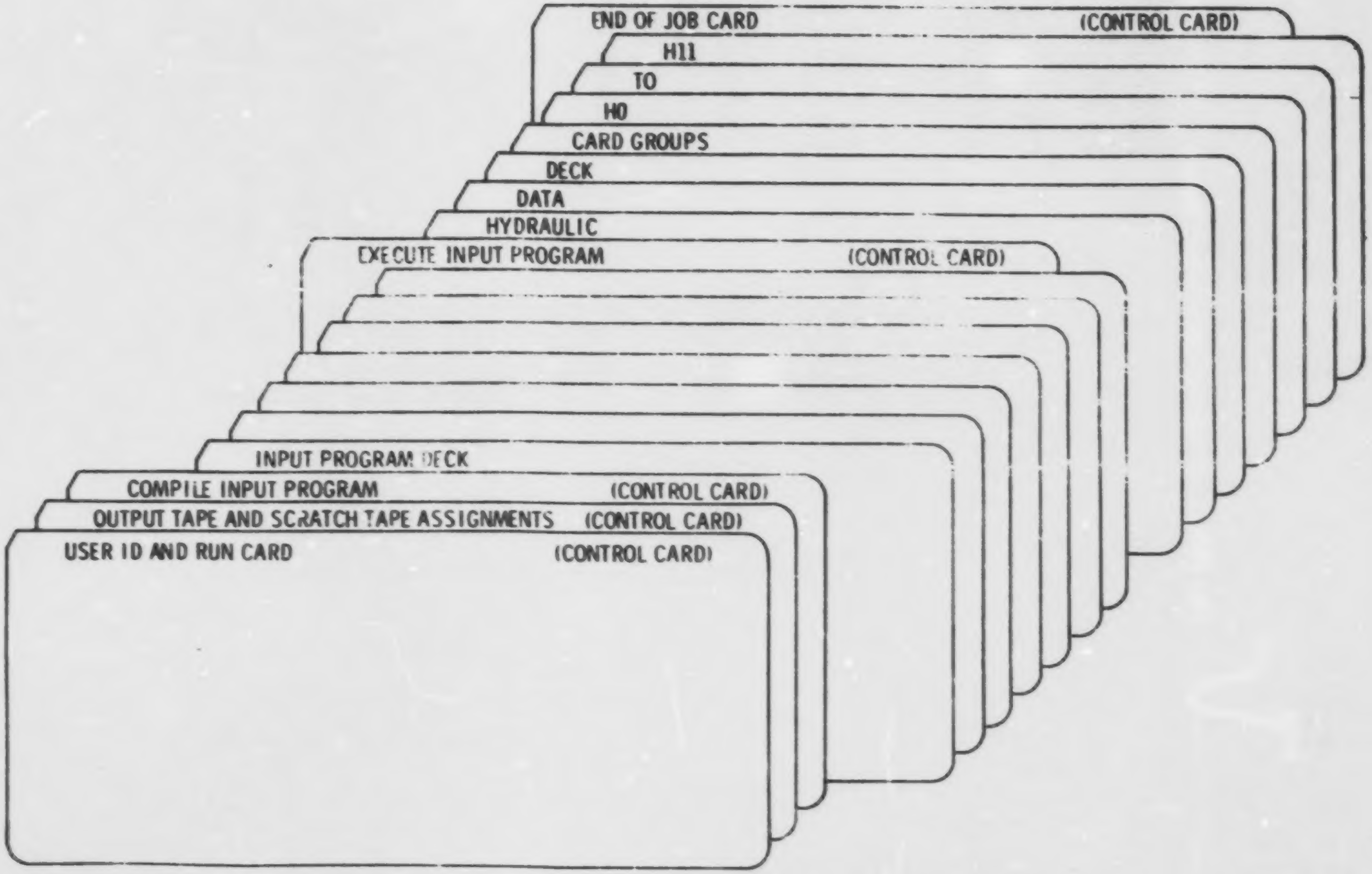

END OF JOB CARD
(CONTROL CARD)
H11
TO
H0
CARD GROUPS
DECK
DATA
HYDRAULIC
EXECUTE INPUT PROGRAM
(CONTROL CARD)
INPUT PROGRAM DECK
COMPILE INPUT PROGRAM
(CONTROL CARD)
OUTPUT TAPE AND SCRATCH TAPE ASSIGNMENTS
(CONTROL CARD)
USER ID AND RUN CARD
(CONTROL CARD)

FIGURE B-6. SAMPLE DATA DECK CONSTRUCTION FOR THE HYDRAULIC INPUT PROGRAM, BNW EXPLORE-I CODE

Computer dependent control cards

```
USER RUN AND ID CARD
ASSIGN UNIT 1 TO A SCRATCH FILE OR SCRATCH TAPE

ASSIGN UNIT 2 TO A PERMANENT FILE OR USER OWNED OR RENTED TAPE
     ( THE HYDRAULIC OUTPUT FOR THE QUALITY CODE WILL BE STORED ON UNIT 2)

UNIT 5 IS THE CARD READER
UNIT 6 IS THE LINE PRINTER


COMPILE THE INPUT PROGRAM
```

The hydraulic input code and hydraulic calculation code require these unit assignments

```
      FORTRAN  CARD DECK OF THE HYDRAULIC INPUT CODE
```

Computer Control Card

```
EXECUTE THE INPUT PROGRAM
```

(START OF THE HYDRAULIC INPUT DATA DECK)

CARD GROUP *REMARKS*

```
H0    BNW EXPLORE-1  VERIFICATION ON THE WILLAMETTE VALLEY
      VERIFICATION  AREA FROM SALEM TO PORTLAND (LOW FLOW SEPT 1967)
H1        2  25.    1.  50.   0.   0.  -0.  -0.    1  -0    2    5
H3        2   1
         33  33
         40  40
H4       52  52
         54  54
         57  57
          1     3.84     9.92     -.00     -.00   -29.28    284.150  798.750
          2    53.62     4.76     -.00     -.00    18.30    297.100  733.460
          3     3.84    19.52     -.00     -.00   -21.25    285.390  788.620
          4     3.84    18.20     -.00     -.00   -14.83    285.500  775.110
          5     3.84     9.60     -.00     -.00   -22.76    290.680  767.010
          6     3.84     9.20     -.00     -.00   -22.36    288.200  758.340
          7     3.89    10.64     -.00     -.00   -10.47    296.990  744.830
          8     4.04     3.60     -.00     -.00    -7.27    297.100  733.120
H5        9    53.63    12.72     -.00     -.00    14.60    289.560  727.600
         10    53.64    11.68     -.00     -.00    20.20    285.390  715.780
         11    53.66    10.36     -.00     -.00    20.30    278.070  714.430
         12    53.69     6.44     -.00     -.00    14.80    268.170  715.220
         13    53.69     9.40     5.00     -.00    21.20    258.600  711.510
         14    53.70     8.24     5.00     -.00    20.60    243.170  706.550
```

FIGURE B-7. LISTING OF INPUT DATA DECK FOR HYDRAULIC CODE

```
CARD GROUP                                                                                    REMARKS

                   15    53.72    8.80      5.00     -.00     21.90     232.370  697.320      JUNCTION
                   16    53.74   10.08      5.00     -.00     26.00     222.010  701.260        CARDS
                   17    53.77   11.36      5.00     -.00     29.40     208.270  708.690
                   18    53.83    6.48      5.00     -.00     32.70     198.930  701.040
                   19    53.96    7.12      5.00     -.00     39.90     199.720  689.330
                   20    54.52    6.08      5.00     -.00     47.20     190.940  686.290
                   21    57.18    7.00      5.00     -.00     49.70     186.430  678.630
                   22    62.35    8.80      5.00     -.00     55.16     194.200  669.510    Note:  There is one
                   23    68.95    8.00      5.00     -.00     61.00     190.260  662.760           H5 card group
                   24    73.02    7.20      5.00     -.00     66.10     195.550  651.950           for each junction
                   25    79.41   10.80      5.00     -.00     71.40     195.100  643.060
                   26    80.99    4.40      5.00     -.00     71.00     186.210  637.430
                   27    81.88    6.00      5.00     -.00     73.50     180.240  631.910
                   28    84.85    7.20      5.00     -.00     82.00     180.350  624.370
                   29    97.25   10.00      5.00     -.00     88.10     178.330  610.750
                   30    98.86    5.38      5.00     -.00     93.70     181.140  601.400
                   31   105.15    8.36     65.60     -.00     99.10     188.570  594.530
                   32   108.79    9.20   6570.00     -.00    103.90     185.760  583.050
                   33    25.64    3.00      -.00     -.00     23.16     308.810  745.170
                   34    51.64    1.80      -.00     -.00     48.86     319.840  749.110
   H5              35    85.93    4.20      4.70     -.00     84.67     328.850  749.330
(continued)        36   135.48    4.10      3.80     -.00    133.30     345.730  747.190
                   37   189.05    4.80      7.50     -.00    187.94     357.100  737.740
                   38   245.20    5.80      -.00     -.00    243.33     358.340  719.950
                   39   298.46    2.40    662.00     -.00    297.56     365.210  714.880
                   40    82.59    2.00       .05     -.00     82.44     282.580  732.330
                   41    96.25    2.40       .48     -.00     95.96     277.510  741.000
                   42   100.49    3.20       .40     -.00    100.20     265.130  746.290
                   43   103.18    2.80       .44     -.00    102.77     249.360  748.090
                   44   105.29    3.40      -.00     -.00    104.90     239.570  747.190
                   45   107.52    2.20       .09     -.00    107.04     234.050  751.810
                   46   109.60    2.20       .09     -.00    109.15     223.810  750.230
                   47   111.66    2.00       .84     -.00    111.17     218.290  753.950
                   48   113.65    1.80       .09     -.00    113.13     209.250  764.980
                   49   115.52    1.00       .45     -.00    114.96     215.930  778.150
                   50   117.46    1.00       .18     -.00    116.80     209.060  781.530
                   51   119.27     .80      8.32     -.00    118.71     203.320  786.820
                   52    73.15    2.20      -.00     -.00     72.79     274.130  705.200
                   53   103.05    2.20     33.80     -.00    102.6[illegible]   280.100  693.940
                   54    65.36    2.16      -.00     -.00     64.92     269.970  707.790
                   55    75.45    2.32      -.00     -.00     74.77     265.240  699.800
                   56    81.97     .80     36.70     -.00     81.34     263.770  690.230
                   57    61.65    3.20      -.00     -.00     61.42     189.920  690.790
                   58    67.60    3.00      -.00     -.00     67.18     183.390  685.840
                   59    72.58    2.44      6.40     -.00     72.21     175.850  687.750
                   60    77.50    1.96      -.00     -.00     77.27     165.720  687.860
                   61    82.47    1.68      -.00     -.00     82.05     156.370  682.570
                   62    86.98    1.52      -.00     -.00     86.59     150.740  675.140
                   63    91.53    1.24      9.90     -.00     91.07     158.400  670.980
   H6           99999
                    1     0     1      10560.000  1136.000  -29.280    .035     .000
   H7               2     2     8         10.000   694.000    5.515    .035     .000
```

FIGURE B-7 (continued)

CARD GROUP

REMARKS

H7
(continued)

3	1	3	10032.000	1044.000	-25.265	.035	-.132
4	3	4	13728.000	1089.000	-18.040	.035	-.212
5	4	5	10032.000	1128.000	-18.795	.035	-.234
6	5	6	10032.000	848.000	-22.560	.035	-.288
7	6	7	17952.000	645.000	-16.415	.035	-.529
8	7	8	14784.000	694.000	-8.870	.035	-.748
9	2	9	10032.000	785.000	16.450	.035	-.234
10	9	10	13200.000	387.000	17.400	.035	-.486
11	10	11	17952.000	442.000	20.250	.035	-.461
12	11	12	12144.000	274.000	17.550	.035	-.681
13	12	13	9504.000	550.000	18.000	.035	-.343
14	13	14	15840.000	523.000	20.900	.035	-.393
15	14	15	15840.000	426.000	21.250	.035	-.487
16	15	16	12144.000	534.000	23.950	.035	-.423
17	16	17	16896.001	542.000	27.700	.035	-.476
18	17	18	12672.000	393.000	31.050	.035	-.751
19	18	19	12672.000	411.000	36.300	.035	-.928
20	19	20	10560.000	417.000	43.550	.035	-1.501
21	20	21	11616.000	375.000	48.450	.035	-2.409
22	21	22	15840.000	318.000	52.400	.035	-2.853
23	22	23	15840.000	268.000	58.050	.035	-3.277
24	23	24	13200.000	321.000	63.550	.035	-2.794
25	24	25	13200.000	257.000	68.750	.035	-3.475
26	25	26	10560.000	332.000	71.200	.035	-2.230
27	26	27	7920.000	369.000	72.250	.035	-1.964
28	27	28	7920.000	465.000	77.750	.035	-2.548
29	28	29	13200.000	270.000	85.050	.035	-4.104
30	29	30	10560.000	481.000	90.900	.035	-1.930
31	30	31	13200.000	414.000	96.400	.035	-2.859
32	31	32	11616.000	523.000	101.500	.035	-2.296
33	7	33	10560.000	142.000	12.340	.055	-2.175
34	33	34	15840.000	151 000	36.010	.055	-2.036
35	34	35	15840.000	189 000	66.765	.055	-1.951
36	35	36	21120.000	196.000	108.985	.055	-1.824
37	36	37	21120.000	211.000	160.620	.055	-1.835
38	37	38	21120.000	251 000	215.635	.055	-1.758
39	38	39	15840.000	259.000	270.445	.055	-1.870
40	9	40	9500.000	90 000	67.950	.035	-.647
41	40	41	16896.001	110 500	89.200	.035	-.417
42	41	42	15840.000	116.500	98.080	.035	-.303
43	42	43	21120.060	110.000	101.485	.035	-.239
44	43	44	21120.000	105.000	103.835	.035	-.232
45	44	45	21120.000	87.000	105.970	.035	-.250
46	45	46	21120.000	83.500	108.095	.035	-.253
47	46	47	21120.000	78.500	110.160	.035	-.255
48	47	48	23760.000	68.000	112.150	.035	-.250
49	48	49	18480.000	55.000	114.045	.035	-.287
50	49	50	21120.000	48.000	115.880	.035	-.292
51	50	51	21120.000	49.500	117.755	.035	-.283
52	11	52	10560.000	104.000	63.030	.035	-.896
53	52	53	21120.000	104.000	87.710	.035	-.832
54	11	54	10560.000	102.000	59.080	.035	-.801

FIGURE B-7 (continued)

CARD GROUP *REMARKS*

```
                55  54  55        21120.000  106.000   69.845    .035    -.623
                56  55  56        15840.000   98.000   78.055    .035    - 616
                57  19  57        10560.000  152.000   57.570    .035    -.425
H7              58  57  58        21120.000  146.000   64.300    .035    - 334
(continued)     59  58  59        21120.000  128.000   69.695    .035    -.347
                60  59  60        21120.000  104.000   74.740    .035    -.286
                61  60  61        21120.000   36.000   79.660    .035    -.306
                62  61  62        21120.000   75.000   84.320    .035    -.337
                63  62  63        21120.000   65.000   88.830    .035    -.350
H8             99999
                MORRISION BRIDGE STAGE VERSUS TIME NODE
                $CARD1 KO=0,NI= 17, MAXIT=50,  TT=0., 1., 2., 4., 5., 6., 9., 10., 13.
H9                     , 14.,15., 16., 17., 18., 19., 22., 25.,  YY=4.05, 3.90, 4.05,     Tidally influenced
                       6.10,6.40,5.85, 4.75, 4.55, 3.85, 3.80, 4.15, 5.70, 6.55,          controlled node
                       6.75, 6.30, 5.05, 4.05
                $END                                                                        Willamette Falls
                WILLAMETTE FALLS CONTROLLED NODE (WEIR FORMULA)                             controlled node
                   2029.      52.0       2.5                                                (End of input card)
H11            ********************************************************************************

                                 (End of Input Card Deck)
Computer       COMPILE THE CALCULATION PROGRAM
Control Card



                   FORTRAN CARD DECK OF THE HYDRAULIC CALCULATION CODE



Computer
Control Card   EXECUTE THE CALCULATION PROGRAM
CARD GROUP                   (START OF THE OUTPUT PRINT-PLOT PUNCH REQUEST DECK)             REMARKS
P1               1
P2              WILLAMETTE   PORTLAND-WILLAMETTE FALLS
P3                   1         2
P4                   8
P5               1  3  4  5  6  7  8  2
P6                   8
P7               1  3  4  5  6  7  8  2
P8               1
                WILLAMETTE   FALLS TO YAMHILL MOUTH
   •                 1         2
   •                 13                                                                       Repeat of P2-P8
   •             2  9 10 11 12 13 14 15 16 17 18 19 20
```

FIGURE B-7 (continued)

```
CARD GROUP                                                                                  REMARKS

                   13
                2   9  10  11  12  13  14  15  16  17  18  19  20
                 0
               WILLAMETTE    YAMHILL MOUTH -SALEM
                    1           2
                   13
                20  21  22  23  24  25  26  27  28  29  30  31  32              Repeat of P2-P8
                   13
                20  21  22  23  24  25  26  27  28  29  30  31  32
                 0
               CLACKAMAS TRIBUTARY
                    1           2                                               Repeat of P2-P8
                    8
                 7  33  34  35  36  37  38  39
                    8
                 7  33  34  35  36  37  38  39
                 0
               TUALATIN TRIBUTARY
                  - 1           2                                               Repeat of P2-P8
                   13
                 9  40  41  42  43  44  45  46  47  48  49  50  51
                   13
                 9  40  41  42  43  44  45  46  47  48  49  50  51
                 0
               MOLALLA TRIBUTARY
                    1           2                                                     •
                    3
                11  52  53
                    3
                11  52  53
                 0
               PUDDING TRIBUTARY
                    1           2                                                     •
                    4
                11  54  55  56
                    4
                11  54  55  56
                 0
               YAMHILL TRIBUTARY
                    1           2
                    8                                                           Repeat of P2-P8
                19  57  58  59  60  61  62  63
                    8
                19  57  58  59  60  61  62  63
                 0
                        (END OF PRINT-PLOT-PUNCH REQUEST DECK)
COMPUTER
CONTROL CARD   END OF RUN CARD
```

FIGURE B-7 (continued)

TABLE B-2

HYDRAULIC DATA CARD FORMAT FOR EXPLORE-I

Card Group	Format	Columns	Description	Variable Name	Default Value
H0	15A4	1-60	Title for run (card 1)	ALPHA (1-15)	none
	15A4	1-60	Title for run (card 2)	ALPHA (16-30)	none
			Hydraulic control card		
H1	I5	1-5	Number of the last tidal day cycle to be simulated	NTCYC	none
	3F5.0	6-10	Number of hr/tidal day cycle	PERIOD	none
		11-15	Length of quality time step, hour (must be evenly divisible into PERIOD)	QINT	none
		16-20	Length of hydraulic time-step, second (must be evenly divisible into QINT)	DELT	none
	5X				
	3F5.0	26-30	Evaporation rate (inches/month)	EVAP	none
		31-35	Wind velocity, mph	WIND	none
		36-40	Wind direction, clockwise, degrees from North	WDIR	none
	4I5	41-45	Tidal day number where printed output will start and the quality tape will be prepared	NQSWRT	none
		46-50	Number of junctions with time varying inflow	NJSW	none
		51-55	Number of controlled junctions	NJGW	none
		56-60	Number of tributary channels	NTRIB	none

Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
			[Junction numbers where hydrograph inflows are present]		
H2	I5	1-5	Junction number where first hydrograph inflow is present	JSW(1)	none
	I5	6-10	Junction number where second hydrograph input is present	JSW(2)	none
	. . .	. . .		. . .	. . .
			Junction number where last hydrograph input is present	JSW(NJSW)	none
			[Codes which indicate the type of controlled node (a number from 1-6) 1 means weir relationship (A1, A2, A3 needed) 2 means tidally influenced 3 means dam operated from Q vs H curve 4 means dam head and outflow determined from H vs t and Q vs t curves 5 means only dam head determined from H vs t curve 6 means only dam outflow determined from Q vs t curve]		
H3	I5	1-5	Code for the first controlled node	JGW(1)	none
	I5	6-10	Code for the second controlled node	JGW(2)	none
	. . .	. . .			
			Code for the last controlled node	JGW(NJGW)	none

Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
			[There will be NTRIB H4 data cards]		
H4	2I5	1-5	Channel number of the Ith tributary channel	ITRIB(I,1)	none
		6-10	Junction number of the first upstream node in the small tributary	ITRIB(I,2)	none
			[Repeat this card for each junction]		
			[Junction cards (maximum = 500)]		
H5	I5	1-5	Junction number	J	none
	F10.0	6-15	Water surface-elevation (ft)	HEAD(J)	none
	F10.0	16-25	Surface area of junction (millions of sq ft)	AS(J)=SURF	none
	F10.0	26-35	Constant flow input to the junction (cfs)	QIN(J)=QF1	none
	F10.0	36-45	Constant flow out of the junction (cfs)	QOU(J)=QF2	none
	F10.0	46-55	Junction bottom elevation in feet	DEP(J)=DT	none
	5X	56-60	Leave columns blank		
	F10.0	61-70	X-coordinate (thousands of ft)	X(J)=X1	none
	F10.0	71-80	Y-coordinate (thousands of ft)	Y(J)=Y1	none
H6	I5	1-5	To terminate junction cards, write 99999.		none

Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
H7			[Repeat this card group for each channel being simulated. (maximum = 600)]		
	5I5	1-5	Channel number	N	none
		6-10	Junction at lower end of channel	NTEMP(1)	none
		11-15	Junction at upper end of channel	NTEMP(2)	none
	5F10.0	26-35	Length of channel (ft)	ALEN	none
		36-45	Width of channel (ft)	WIDTH	none
		46-55	Average elevation of channel bottom (ft)	RAD	none
		56-65	Manning's coefficient for the channel	COEF	none
		66-75	Initial velocity (fps)	VEL	0.0
H8	I5	1-5	To terminate channel cards, write 99999.		none

Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
			[Card group H9 is used to specify the time varying and/or constant data for the controlled nodes. The type of controlled node was specified on card group H4 above. There must be one set of H9 cards for each controlled node. The first set inputs the information for the first controlled node, the second set for the second controlled node, etc. The format of the H9 cards depends upon which type of controlled node has been specified. The formats are as follows:]		
			[WEIR TYPE (code = 1)]		
H9a	20A4	1-80	Title card		
H9b	3F10.0	1-10	Weir coefficient	A0(1,J,1)	none
		11-20	Weir crest elevation, ft	A0(1,J,2)	none
		21-30	Weir exponent	A0(1,J,3)	none
			[TIDALLY INFLUENCED NODE (code = 2)]		
H9a	20A4	1-80	Title card		
H9b	Namelist option				
		2-6	Place $CARD1 in columns 2-6.		
		7-72	K0 = (0 or 1, If 0 is used input is ignored. If 1 is used a full tidal cycle will be generated from only four points entered below), NI = (number of tidal stage data points), MAXIT = (Maximum number of iterations for curve fit, usually 50), TT = (list the values of the time points separated by commas at which data will be specified), YY = (values of the tidal		

Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
			stage separated by commas, which correspond in order to the time values listed above.)		
			The $CARD1 can consist of more than one card but all data and separating commas must be listed between columns 2-72 on each card.		
H9c		2-6	Place $END in columns 2-5 to indicate the end of the data.		

The formats for the remaining four types of controlled nodes are the same.

The rest of the controlled node types and the flow hydrograph inputs specify inputs which can be time varying functions. The following NAMELIST option is used for these inputs. For each variable the input format is one set of cards as follows:

Title card
$CARD1
$END

Columns 20-80 of the title card is used as a free field to identify the data. If the word CONST is placed in columns 2-6 of the title card then the $CARD1 and $END cards will not be used. Instead the number listed in columns 7-18 of the title card will be used as a constant value for the variable. If the input is to specify a time varying function (i.e. CONST does not appear in columns 2-6 of the title card) the $CARD1 must be present and have the following form:

(continued on next page)

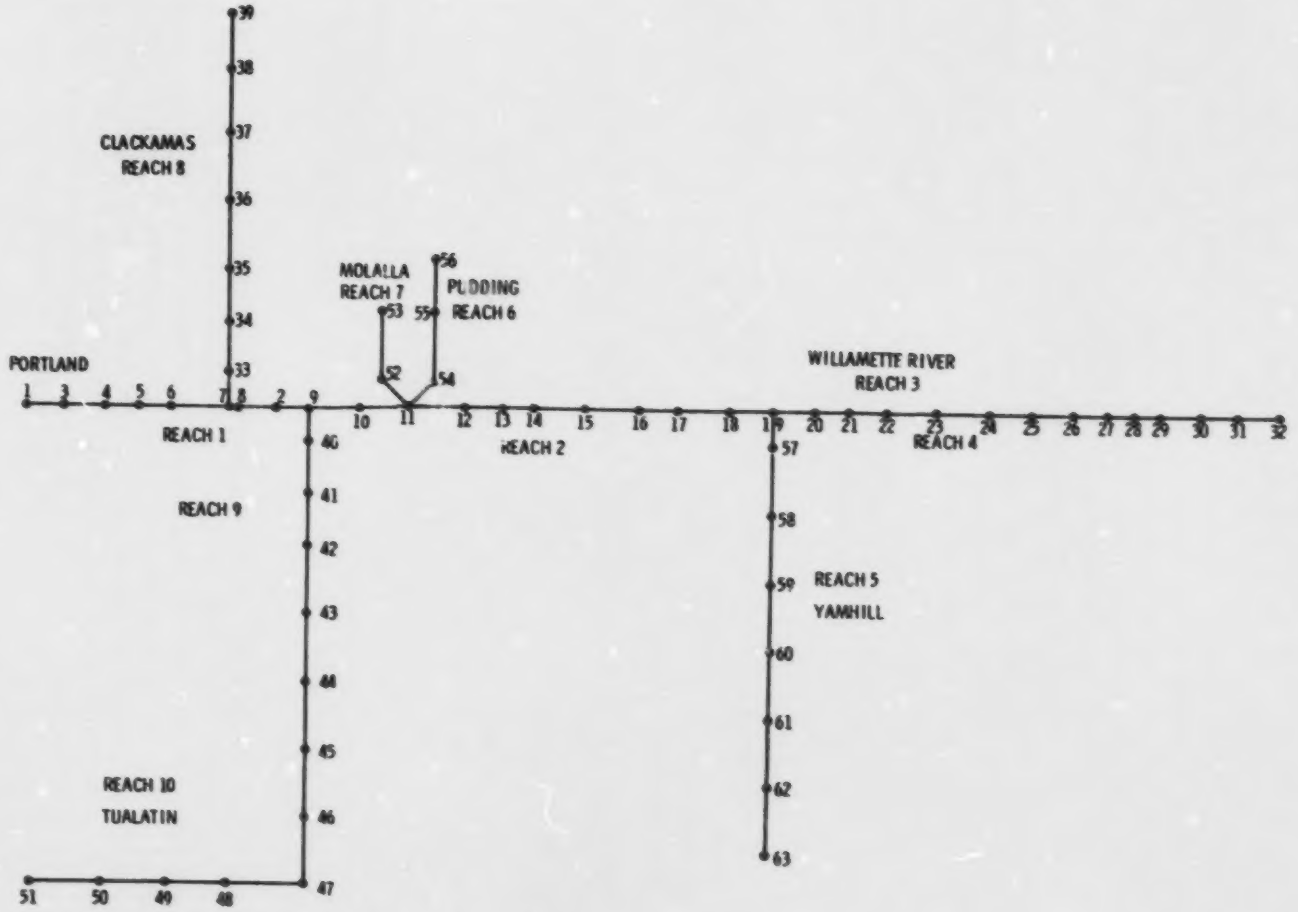
Table B-2 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
		Column 2-6	$CARD1		
		Column 7-72	M = (number [integer] of data points used), MIN = (number [integer] giving minimum order of polynomial to be used to fit data), MAX = (number [integer] giving maximum order or polynominal to be used to fit data), X = (a list of time values separated by a comma), Y = (a list of the values, separated by a comma, of the function corresponding to the time values specified by X above)		
		The $CARD1 can consist of more than one card but all data (including the separating commas) must be listed between columns 2-72 on each card.			
			[Q vs H Dam (code = 3)]		
H9a-c	NAMELIST Option		Values of flows and heads (the head corresponds to X = in the discussion above and the flow to Y =)		
			[H vs t and Q vs t Dam (code = 4)]		
H9a-c	NAMELIST Option		Values of head and times		
H9b-c	NAMELIST Option		Values of flow and times		
			[H vs t Dam (code = 5)]		
H9a-c	NAMELIST Option		Values of head and times		
			[Q vs t Dam (code = 6)]		
H9a-c	NAMELIST Option		Values of flow and times		

Table B-2 (continued)

Data Group	Format	Columns	Description	Variable Name	Default Value
	[Hydrograph input cards. One set of H10 cards must be present for each input node, specified on card H2 above. The first set of hydrograph input cards is for the first input node above, the second for the second node, etc. The NAMELIST option is used on these cards and is discussed above.]				
H10	NAMELIST Option		Values of flow and times		
H11	Must contain all asterisks and is the terminator card for the hydrodynamic input deck.				

FIGURE B-8. WILLAMETTE RIVER BASIN SIMULATION FROM SALEM TO PORTLAND


PORTLAND
CLACKAMAS
REACH 8
MOLALLA
REACH 7
PUDDING
REACH 6
WILLAMETTE RIVER
REACH 3
REACH 1
REACH 2
REACH 4
REACH 9
REACH 5
YAMHILL
REACH 10
TUALATIN
1
3
4
5
6
7
8
2
9
10
11
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Print-Plot-Punch Options Available and Instructions for the Print-Plot-Punch Data Deck Preparation

No output is printed or plotted while the hydraulic code is running. As the program is run, a scratch file of the time history of the flows, velocities, heads, inflow, outflow, and volumes for all the junctions and channels is written to tape. These values are output once, as average values, for each quality time step. This scratch file begins with tidal day NQSWRT and is written through tidal day NTCYC. Since a hydraulic model of a river basin can produce voluminous output, the code has been set up to allow selection of junctions and channels in user-grouped and labeled sets of 20 or less for print and/or lineprinter plot output. Any particular or contiguous set of 7 or less simulated tidal days starting with tidal day NQSWRT can be specified. Limiting the output to groups of 20 or fewer junctions and channels will prevent production of unwanted volumes of printout. However, since at times the user may want printout for more than 20 junctions and channels, as many groups of 20 or less as are needed may be requested. An advantage of this method is that the output can be ordered into reaches or tributaries. The user can also request the punching of a restart hydraulic deck.

Table B-3 gives the order and format of the Punch-Print-Plot request deck and Figure B-9 shows the data deck construction for running the BNW EXPLORE-I hydraulic calculation code. Figure B-7 is a sample listing of the data deck for this option.

QUALITY PROGRAM INPUT INSTRUCTIONS AND OUTPUT FORMATS

Quality Models

The quality model consists of a number of interrelated submodels which allow the simulation of the behavior of fifteen quality parameters. The general relationship of these models is shown in Figure B-10. Because calibration of the entire model would require a large amount of measured data, a number of options have been provided to simplify the relationships shown in Figure B-10. This allows portions of the model to be used when limited data are available.

Each of the submodels is discussed in detail in the literature review (Appendix A) and model selection sections of this report; in addition, they are summarized in Table B-4 for the user's convenience. Table B-4 also defines the necessary input variables, along with a range of common values and a mean value for each variable. A number of the input variables are first order rate reaction constants. Table B-4 lists values for these constants to the base of the natural logarithms (base e) because this value is used in the code.

TABLE B-3

CONTROL CARDS FOR REQUESTING PUNCH, PRINT AND PLOT OUTPUT

Card Group	Format	Columns	Description	Variable Name	Default Value
P1	I5	1-5	Switch to request the punching of a restart deck. Any number other than 0 causes a restart deck to be punched.	IDECK	none
	Card groups P2 - P8 are repeated for each group of 20 or less junctions and channels to be printed and/or plotted.				
P2	20A4	1-80	Descriptive title for the group of junction and channel data to be printed and/or plotted	RUNT/T(I) I=1, 20	none
P3	2I10	1-10	The number of tidal day where printing and/or plotting will commence	IDAY1	$\geq$ NQSWRT $\leq$ IDAYL
		11-20	The number of the last tidal day to be printed and/or plotted (note IDAYL - IDAY1 is limited to be $\leq$ 7)	IDAYL	$\geq$ NQSWRT $\leq$ NTCYC
P4	I10	1-10	The number of junctions for which print and/or plot information is requested	NJP	$\leq$ 20
P5	20I5	1-4 5-8 9-12 . . . 76-80	Array of NJP junction numbers for which printout is desired (the junction printout will be in the order dictated by this array)	NJW(1) NJW(2) NJW(3) . . . NJW(20)	none

Table B-3 (continued)

Card Group	Format	Columns	Description	Variable Name	Default Value
P6	I10	1-10	The number of channels for which print and/or plot information is requested	NCP	≤ 20
P7	20I4	1-4 5-8 9-12 . . . 77-80	Array of NCP channel numbers for which print and/or plot information is desired (The channel printout will be in the order dictated by this array.)	NCW(1) NCW(2) NCW(3) . . . NCW(20)	none
P8	I5	1-5	Switch to request plots for the channel flows and junction heads (NPLOTS = 0, then suppress the plots)	NPLOTS	none

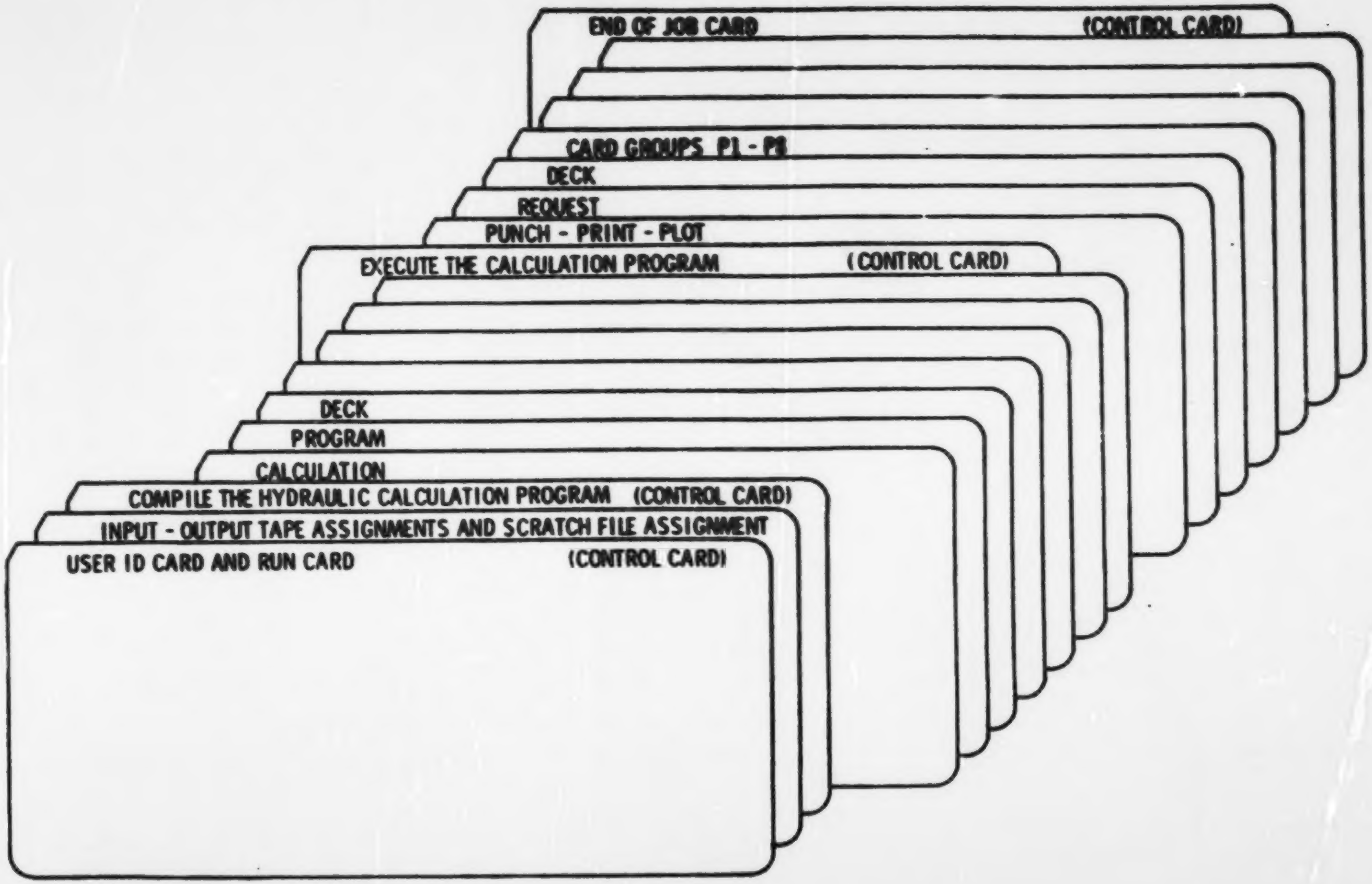

END OF JOB CARD
(CONTROL CARD)
CARD GROUPS P1 - P8
DECK
REQUEST
PUNCH - PRINT - PLOT
EXECUTE THE CALCULATION PROGRAM
(CONTROL CARD)
DECK
PROGRAM
CALCULATION
COMPILE THE HYDRAULIC CALCULATION PROGRAM
(CONTROL CARD)
INPUT - OUTPUT TAPE ASSIGNMENTS AND SCRATCH FILE ASSIGNMENT
USER ID CARD AND RUN CARD
(CONTROL CARD)

FIGURE B-9.· SAMPLE DATA DECK CONSTRUCTION FOR EXECUTING THE BNW EXPLORE-I HYDRAULIC CODE

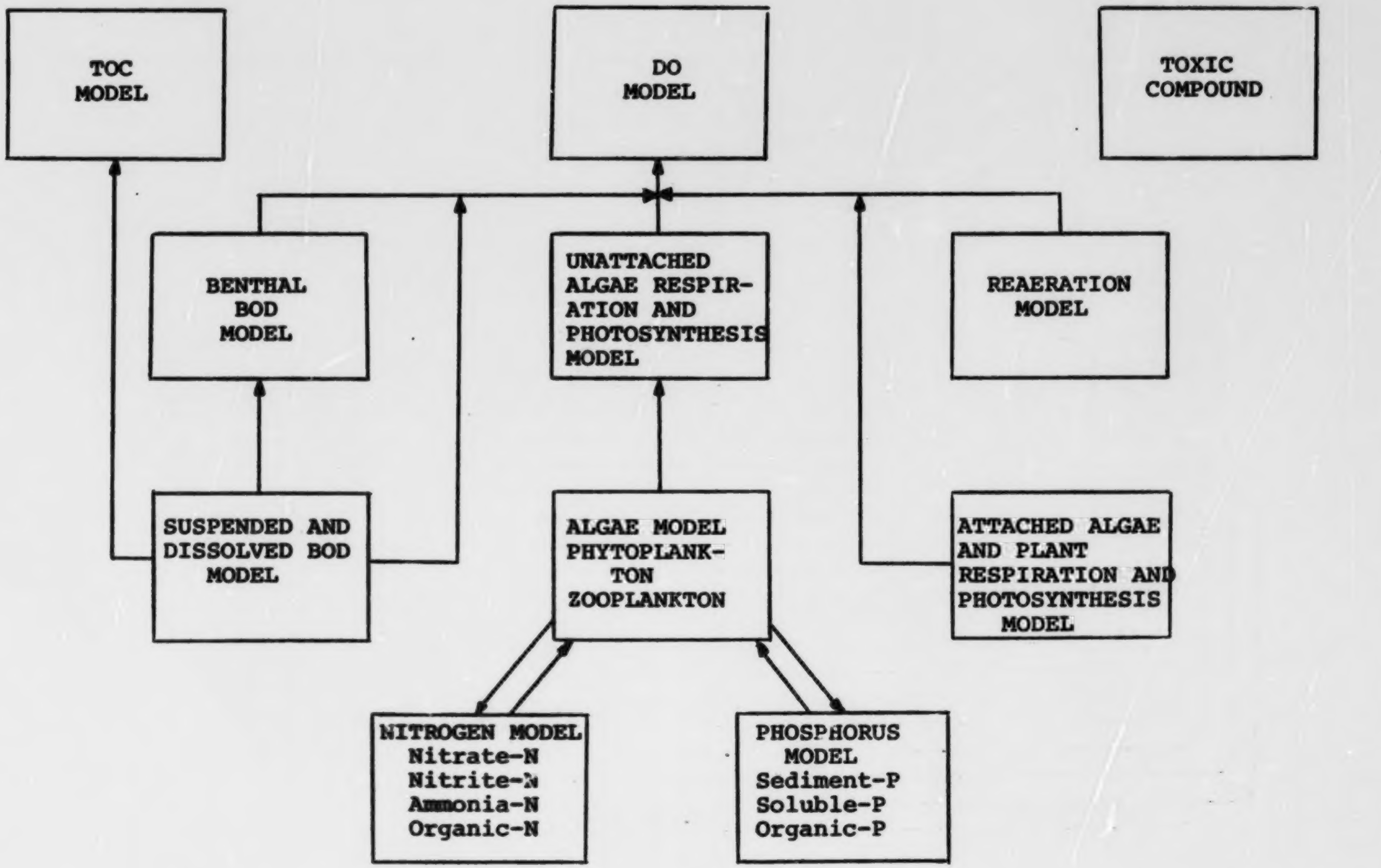

TOC MODEL
DO MODEL
TOXIC COMPOUND
BENTHAL BOD MODEL
UNATTACHED ALGAE RESPIR-ATION AND PHOTOSYNTHESIS MODEL
REAERATION MODEL
SUSPENDED AND DISSOLVED BOD MODEL
ALGAE MODEL PHYTOPLANK-TON ZOOPLANKTON
ATTACHED ALGAE AND PLANT RESPIRATION AND PHOTOSYNTHESIS MODEL
NITROGEN MODEL
Nitrate-N
Nitrite-N
Ammonia-N
Organic-N
PHOSPHORUS MODEL
Sediment-P
Soluble-P
Organic-P

FIGURE B-10. INTEGRATED MODELS

TABLE B-4

QUALITY SUBMODEL DEFINITION

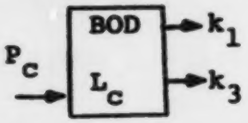
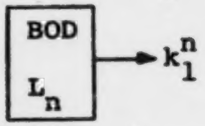
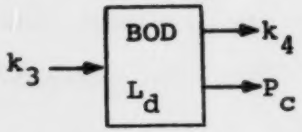
GOVERNING EQUATION	INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
Carbonaceous BOD, L_c	k_1^{20} /day deoxygenation constant at 20°C	0.1-0.8	0.3
	k_3 /day sedimentation constant	0-1.5	0.0
	θ_c - temperature constant	1.0-3.6	1.05
$\frac{dL_c}{dt} = -(k_1+k_3)\ L_c+P_c$	P_c $\frac{mg}{\ell day}$ scour constant	0.0-0.8	-
	L_c $\frac{mg}{\ell}$		
$k_1 = k_1^{20}\ \theta_c^{(T-20)}$			
Nitrogenous BOD, L_n	k_1^{n20} /day deoxygenation constant at 20°C	0.0-0.8	0.1
	θ_n - temperature constant	1.0-1.6	1.05
	L_n $\frac{mg}{\ell}$		
$\frac{dL_n}{dt} = -\ k_1^n\ L_n$			
$k_1^n = k_1^{n20}\ \theta_n^{(T-20)}$			
Benthic BOD, L_d	k_4^{20} $\frac{1}{day}$ deoxygenation constant at 20°C	0.0-0.8	.1
	θ_ℓ temperature constant	1.04-1.07	1.05
	H water depth		
$\frac{1}{H}\frac{dL_d}{dt} = -\ k_4\ \frac{L_d}{H} + k_3L_c-P_c$	L_d $\frac{g}{m^2}$		
$k_4 = k_4^{20}\ \theta_\ell^{T-20}$			

Table B-4 (continued)

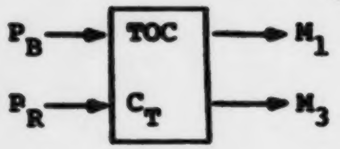
GOVERNING EQUATION	INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
Total Organic Carbon, C_T	M_1^{20} /day deoxygenation constant at 20°C	0-0.8	0.3
	M_3 /day sedimentation constant	0-3.5	0.0
	P_B $\frac{mg}{l\text{-day}}$ scour constant for biologically degradable organic carbon	0.0-0.8	-
$\frac{dC_T}{dt} = -(M_1+M_3)A_BL_C - M_3C_R + P_B+P_R$	P_R $\frac{mg}{l\text{-day}}$ scour constant for refractory organic carbon	0.0-0.8	-
	θ_m - temperature constant	1.0-1.6	1.05
$C_T = A_BL_C+C_R$	A_B - proportionality constant	10.0	10.0
$M_1 = M_1^{20}\ \theta_M^{(T-20)}$			
Toxic Compound, T_c	a_{20}/day decay constant at 20°C	-	-
$\frac{dT_c}{dt} = -a\ T_c^n$	n - power for decay process	-	-
$a = a_{20}\ \theta_T^{(T-20)}$	θ_T - temperature constant	1.0-1.6	1.047
Reaeration Coefficient, k_2	r_1 - multiplier for general model	2.0-12.0	11.5
general model $k_2^{20} = r_1 \frac{v^{r_2}}{H^{r_3}}$	r_2 - velocity exponent	0.5-1.0	1.0
	r_3 - depth exponent	1.67-1.75	1.67
O'Connor-Dobbins model	D_m $\frac{ft^2}{sec}$ film diffusion coefficient	0.01-0.02	0.02
$k_2^{20}\ \alpha\ D_m^{1/2}$	θ_k - temperature, constant	1.0-1.4	1.02
$k_2 = k_2^{20}\ \theta_k^{(T-20)}$			

Table B-4 (continued)

GOVERNING EQUATION	INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
	P_a $\frac{mg\text{-}c}{\ell}$ carbon equivalent for phytoplankton concentration		
Photosynthesis and Respiration due to Suspended Algae, $(P\text{-}R)_s$	A_1 $\frac{mg/\ell}{day\ \frac{mg\text{-}c}{\ell}}$ constant	±(0.1-2.0)	-
For model coupled with algae	A_2 $\frac{mg/\ell}{day\ \frac{mg\text{-}c}{\ell}}$ constant	±(0.1-2.0)	-
$(P\text{-}R)_s = [A_1 \cos(\omega t+\phi)$	ω 2π/hours period	-	-
$+ A_2 \cos(2\omega t+\alpha)]P_a$	ϕ,α radians phase angles	-	-
For model not coupled with algae	A_1 $\frac{mg/\ell}{day}$ constant	±(0.1-2.0)	-
$(P\text{-}R)_s = A_1\cos(\omega t+\phi)$	A_2 $\frac{mg/\ell}{day}$ constant	±(0.1-2.0)	-
$+ A_2\cos(2\omega t+\alpha)$	ω 2π/hours period	-	-
	ϕ,α radians phase angles	-	-
Photosynthesis and Respiration due to Attached Algae and Plants $(P\text{-}R)_a$	A_1 $\frac{mg/\ell}{day}$ constant	±(0.1-2.0)	-
	A_2 $\frac{mg/\ell}{day}$ constant	±(0.1-2.0)	-
$(P\text{-}R)_a = A_1^a\cos(\omega_a t + \phi_a)$	ω 2π/hours period	-	-
$+ A_2^a\cos(2\omega_a t + \alpha_a)$	ϕ,α radians phase angles	-	-

Table B-4 (continued)

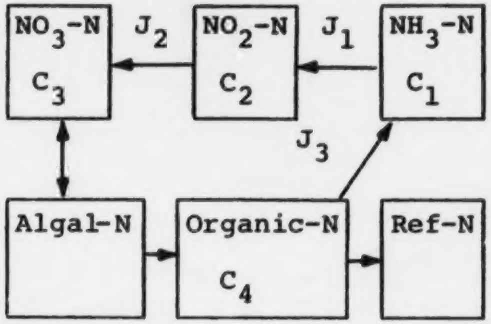
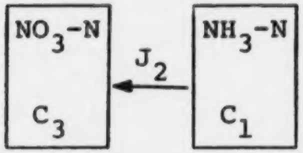
GOVERNING EQUATION	INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
Nitrogen			
Algal Nitrogen Model			
 NO$_3$-N C$_3$ J$_2$ NO$_2$-N C$_2$ J$_1$ NH$_3$-N C$_1$ J$_3$ Algal-N Organic-N C$_4$ Ref-N	J_1 /day rate constant from ammonia to nitrite	0.1-0.5	0.30
	J_2 /day rate constant from nitrite to nitrate	5.0-10.0	7.50
	J_3 /day rate constant from organic-N to ammonia	0.1-0.4	0.25
$\frac{dC_1}{dt} = - J_1C_1+J_3C_4$ $\frac{dC_2}{dt} = - J_2C_2+J_1C_1$ $\frac{dC_3}{dt} = + J_2C_2 +$ other terms $\frac{dC_4}{dt} = - J_3C_4 +$ other terms			
Ammonia-Nitrate Model	J_2 $\frac{1}{\text{day}}$ rate constant from ammonia to nitrate	0.1-10.0	5.0
 NO$_3$-N C$_3$ J$_2$ NH$_3$-N C$_1$			

Table B-4 (continued)

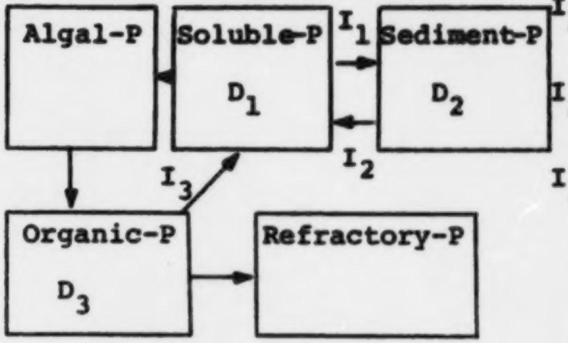
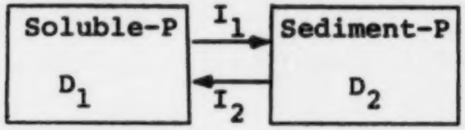
GOVERNING EQUATION	INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
$\frac{dC_1}{dt} = - J_2C_1$			
$\frac{dC_3}{dt} = + J_2C_1$			
Phosphorus			
Algal Phosphorus Model			
 Algal-P Soluble-P D_1 I_1 Sediment-P D_2 I_2 I_3 Organic-P D_3 Refractory-P	I_1 $\frac{1}{day}$ rate constant from soluble-P to sediment-P	0.1-0.7	-
	I_2 $\frac{1}{day}$ rate constant from sediment-P to soluble-P	0.1-0.7	-
	I_3 $\frac{1}{day}$ rate constant from organic-P to soluble-P	0.1-0.7	-
$\frac{dD_1}{dt} = - I_1D_1+I_2D_2$ + other terms			
$\frac{dD_2}{dt} = - I_2D_2+I_1D_1$			
$\frac{dD_3}{dt} = - I_3D_3+$ other terms			
First Order Phosphorus Model			
 Soluble-P D_1 I_1 I_2 Sediment-P D_2	I_1 $\frac{1}{day}$ rate constant from soluble-P to sediment-P	0.1-0.7	0.4

Table B-4 (continued)

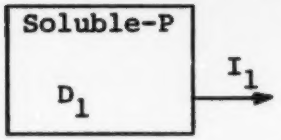
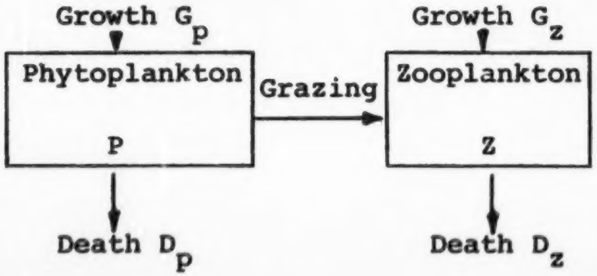
GOVERNING EQUATION	INPUT	VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
$\frac{dD_1}{dt} = - I_1D_1+I_2D_2$	$I_2\ \frac{1}{day}$	rate constant from sediment-P to soluble-P	0.1-0.7	-
$\frac{dD_2}{dt} = - I_2D_2+I_1D_1$				
Second Order Phosphorus Model				
 Soluble-P D_1 I_1	$I_1\ \frac{1}{day}$	second order rate constant for soluble-P decay	0.1-0.7	0.4
$\frac{dD_1}{dt} = - I_1D_1^2$				
Algae Model				
 Growth G_p Phytoplankton P Grazing Growth G_z Zooplankton Z Death D_p Death D_z	F_1	Phytoplankton saturated growth constant (/day-°C)	0.05-0.2	0.1
	f	Photoperiod (day)	0.3-0.7	0.5
	k_e	Extinction coefficient (light attenuation with increasing depth)	0.02-7.1	-
	I_a	Average light intensity	0.25-1.0	-
$\frac{dP}{dt} = (G_p-D_p)P$	I_s	Light intensity at which saturated growth occurs	0.5-1.0	-
$\frac{dZ}{dt} = (G_z-D_z)Z$	K_n	Michaelis constant for nitrogen	0.025	0.025
	K_d	Michaelis constant for phosphorus	0.025	0.025

Table B-4 (continued)

GOVERNING EQUATION		INPUT VARIABLE DEFINITION	RANGE OF VALUES	STANDARD VALUE
$G_p = F_1T \frac{2.718f}{K_eH} (e^{-\alpha_1} - e^{-\alpha_o})$	F_2	Phytoplankton death constant due to respiration	0.01	0.01
$X \left[\frac{N}{K_N+N}\right] X \left[\frac{D}{K_D+D}\right]$	C_g	Zooplankton grazing rate	0.13	0.13
	A_{zp}	Conversion efficiency of phytoplankton to zooplankton	0.6	0.6
$\alpha_1 = \frac{I_a}{I_s} \exp(-k_eH)$	K_{mp}	Michaelis constant for phytoplankton concentration	0.06	0.06
$\alpha_o = \frac{I_a}{I_s}$	A_{NP}	Nitrogen/carbon ratio for phytoplankton	0.05-0.17	0.1
$D_p = F_2T + C_gZ$	A_{DP}	Phosphorus/carbon ratio for phytoplankton	0.024-0.24	0.13
$G_p = A_{zp}C_gK_{mp} (\frac{P}{K_{mp}+P})$	A_{NZ}	Nitrogen/carbon ratio for zooplankton	0.05-0.17	0.1
$D_z = F_3T+F_4$	A_{DZ}	Phosphorus/carbon ratio for zooplankton	0.024-0.24	0.13

Input Instructions

Before the input instructions are presented, a number of the terms used need to be defined. In this program a reach is defined as a group of nodes connected to each other by channels. Since all the input constants listed in Table B-4, as well as temperatures, are specified for each reach, reaches should be chosen to correspond to portions of the rivers, lakes, or estuaries which have similar hydraulic characteristics and reaction constants.

There are four types of nodes in the quality code:

- upstream nodes,
- source nodes,
- dissolved oxygen controlled nodes, and
- regular nodes.

At upstream nodes the quality parameter concentrations are specified by input as either constant or time varying values. Calculations such as reactions or transport into the node are not performed for these nodes, which are normally used at the upstream end of each tributary to specify the quality parameter concentrations as boundary conditions for the problem.

Nodes where waste enters the river system are specified by the user as source nodes. Any node except an upstream one may be designated as a source node.

For every node downstream (seaward) from a controlled node, as specified in the hydraulic code, the dissolved oxygen must be specified; alternatively, the node must be flagged so that it will be calculated. This allows the user to control the DO concentration below a dam or weir to correspond with the discharge policy at that location.

Regular nodes consist of all the nodes in the system not designated above.

A tidal exchange coefficient is provided to allow user control of the quality parameter concentrations returning from the seaward side of a tidally controlled node during the reverse flow associated with an incoming tide. The total mass and total flow out are integrated during periods of outward net flow. When the net flow reverses, a pseudo concentration is formed by dividing the total mass out of each parameter by the total flow out. This concentration is then multiplied by the tidal exchange coefficient to obtain the concentration of the quality parameter transported back into the system.

Time varying functions can be specified for four variables:

- source strengths,
- upstream node concentrations,
- reach temperatures, and
- dissolved oxygen concentrations below hydraulic control nodes.

The user defines these time varying inputs by specifying a series of parameter values and corresponding times. This set of data is then fit with up to a fourth order polynomial.

The input to the quality code consists of twenty-eight card groups, summarized in Table B-5. The instructions for each card group are given in Table B-6.

An annotated example of the input deck is shown in Figure B-11. In order to execute the input code, four magnetic tapes are required:

Unit 1 - scratch tape

Unit 2 - tape containing hydraulic data (generated by hydraulic code)

Unit 3 - tape for writing results of input code calculations

Unit 4 - scratch tape

Figure B-12 is a diagram of the construction of the quality input data deck.

Output Specifications

An input summary is printed out which lists all information input to the quality code. This summary, which is printed when the input code is executed (the quality code need not be executed), consists of six parts:

- data deck display;
- graphs of polynomial fit to time varying data;
- model selections made, a list of nodes in each reach, and a list of source and upstream nodes;

TABLE B-5

CARD GROUPS FOR WATER QUALITY PROGRAM

CARD GROUP	DESCRIPTION
Q1	Title Card
Q2	Model Option
Q3	Upstream Node Specification
Q4	Reach Boundaries
Q5	Source Node Specification
Q6	BOD Constants
Q7	Benthic BOD Constants
Q8	TOC Constants
Q9	Toxic Constants
Q10	DO Production by Phytoplankton
Q11	DO Production by Benthic Plants
Q12	Reaeration Constants
Q13	Phosphorus Constants
Q14	Nitrogen Constants
Q15	Algae Constants
Q16	Initial Concentration Option
Q17	Uniform IC Specification
Q18	Reach IC Specification
Q19	Node IC Specification
Q20	Number of Constant Sources
Q21	Constant Source Values
Q22	Time Varying Source Values
Q23	Reach Temperatures
Q24	DO Below Controlled Node Specification
Q25	Number of Constant Upstream Node Specifications
Q26	Constant Upstream Node Concentrations
Q27	Time Varying Upstream Node Concentrations
Q28	End of Quality Input Data Card

TABLE B-6

INPUT FORMAT FOR WATER QUALITY PROGRAM

Card Group	Format	Columns	Description	Variable	Default Values
Q1	20A4	1-80	Title Card: Quality Identification This title will be printed out on each page of the input data summary.	ALPHAQ	BLANK
Q2			Model Option and Integer Input		
	7I5	1-5	0 for new case 1 for restart case (the hydraulic and quality data tapes will be positioned according to data supplied on card by the user)	ISTART	0
		6-10	1 for both carbonaceous and nitrogenous BOD models 2 for only total BOD model	MODBOD	2
		11-15	1 for rate of DO production due to suspended algae to be proportional to phytoplankton concentration 2 for rate of DO production due to suspended algae to be independent of phytoplankton concentration 3 for rate of DO production due to suspended algae and attached algae and plants to be zero	MODDOX	3
		16-20	1 for general reaeration model 2 for O'Connor-Dobbins model 3 for Dobbins model 4 for Thackston-Krenkel model	MODREA	4
		21-25	1 for algal phosphorus model 2 for first order decay model 3 for second order decay model (model 1 must be used if the algae model is to be used)	MODPHO	2
		26-30	1 for algal nitrogen model 2 for ammonia-nitrate model only (model 1 must be used if the algae model is to be used)	MODTIN	2
		31-35	1 for algae model 2 for no algae model	MODALG	2

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q2	2F10.0	36-45	Tidal exchange coefficient	TIDEXC	1.0
		46-55	Number of divisions time step is to be divided into for integration of quality equations	N1	1.0
	4I10	56-60	Number of tidal cycles to be simulated by quality program	NTQCYC	NONE
		61-65	Number of upstream nodes where quality parameters will be specified	NUPSTR	0
		66-70	Number of reaches specified	NREACH	NONE
		71-75	Number of nodes at which quality parameter sources will be located	NSOURC	NONE
		76-80	1 only if all hydraulic and quality input is constant	ICONST	0
Q3			Upstream node identification--each node where the concentrations are to be specified must be listed. A maximum of 50 nodes can be used (let n = number of the Q3 card, i.e., 1st, 2nd, etc.)	IUPSTR(J)	NONE
	16I5	1-5	Junction number for upstream node number 16(n-1)+1	J=16(n-1)+1	
		5-10	Junction number for upstream node number 16(n-1)+2	16(n-1)+2	
		11-15	" "	"	
		"	" "	"	
		76-80	" 16(n-1)+16	16(n-1)+16	
			Repeat card Q3 until all upstream nodes have been specified.		
Q4			Reach description--one Q4 card must be used for each reach in the system	IRBND(J)	NONE
	16I5	1-5	(The array of junction numbers which form the boundary for the reach--maximum of 16 junctions can be used to form the boundary of a single reach.)	J=1	
		6-10		2	
		11-15		3	
		"		"	
		"		"	
		76-80		16	

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q5			Source junction specification. Each junction having a quality source must be specified. A maximum of 50 junctions can have sources associated with them. (Let n = number of the Q5 card, i.e., 1st, 2nd, etc.)	ISOP(J)	NONE
		1-5	Junction number for source number 16(n-1)+1	J=16(n-1)+1	
		6-10	" " 16(n-1)+2	16(n-1)+2	
		"	" "	"	
		76-80	" " 16(n-1)+16	16(n-1)+16	
			Repeat card Q5 until all junctions with sources have been listed.		
			Water Quality Constants Cards (Cards Q6 through Q17) All of the water quality input constants must be specified for each reach defined above. There are ten sets of cards used to specify these input parameters. They are:		

Card Group No.	Constant
Q6	BOD
Q7	Benthic BOD
Q8	TOC
Q9	Toxic compound
Q10	DO production by phytoplankton
Q11	DO production by benthic plants
Q12	Reaeration
Q13	Phosphorus
Q14	Nitrogen
Q15	Algae

Card Group	Format	Columns	Description	Variable	Default Values
			The first card in each set identifies the reaches over which specific constant values apply. The succeeding cards list the constant values. This sequence is repeated in each card group until values have been assigned for all reaches.		
Q6			BOD Constants		
Q6a	20I4	1-4	The array of reach numbers specifying the reaches that are to have the BOD constants listed on card Q6b below		NONE

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q6a	20I4	5-8			
		"			
		"			
		77-80			
Q6b	6F10.4	1-10	Carbonaceous BOD (or total BOD if MODBOD=2) deoxygenation rate constant at 20°C, k_1^{20}, $\frac{1}{\text{day}}$	BODIN(I,K) K = 1	0
		11-20	Sedimentation rate constant, k_3, $\frac{1}{\text{day}}$	K = 2	0
		21-30	Scour rate constant, P_c, mg/ℓ day	K = 3	0
		31-40	Temperature coefficient for carbonaceous deoxygenation constant, θ_c	K = 4	1.0
		41-50	Nitrogenous BOD deoxygenation rate constant at 20°C, k_1^{20}, $\frac{1}{\text{day}}$	K = 5	0.0
		51-60	Temperature coefficient for nitrogenous deoxygenation constant, θ_n	K = 6	1.0
			(Cards 6a and 6b must be repeated until the BOD constants are specified for all reaches. To terminate reading of the BOD cards, use card Q6c below.)		
Q6c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q7			Benthic BOD Constants		
Q7a	20I4	1-4	The array of reach numbers specifying the reaches that are to have the benthic BOD constants listed on card Q7b below		NONE
		5-8			
		"			
		77-80			

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q7b	2F10.4	1-10	Benthic BOD deoxygenation rate constant at 20°C, k_4^{20}, $\frac{1}{\text{day}}$	BENIN(I,K) K = 1	0.0
		11-20	Temperature coefficient for benthic BOD deoxygenation constant, θ_ℓ	K = 2	1.0
			(Cards Q7a and Q7b must be repeated until the benthic BOD constants are specified for each reach. To terminate reading of the benthic BOD constants use card Q7c below.)		
Q7c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q8			TOC Constants		
Q8a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			
Q8b	6F10.4	1-10	Total organic carbon deoxygenation rate constant at 20°C, m_1, $\frac{1}{\text{day}}$	TOCIN(I,K) K = 1	0.0
		11-20	Sedimentation rate constant, m_3, $\frac{1}{\text{day}}$	K = 2	0.0
		21-30	Proportionality constant, A_B	K = 3	0.0
		31-40	Scour rate constant for biologically degradable OC, P_B, mg/ℓ day	K = 4	0.0
		41-50	Scour rate constant for refractory OC, P_R, mg/ℓ day	K = 5	0.0
		51-60	Temperature coefficient for TOC deoxygenation rate constant, θ_m	K = 6	1.0
			(Repeat cards Q8a and Q8b as necessary)		
Q8c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q9			Toxic Constants		NONE
Q9a	20I4	1-4	Array of reach numbers		
		5-8			
		"			
		77-80			
Q9b	3F10.4	1-10	Toxic decay constant at 20°C, a, $\frac{1}{\text{day}}$	TOXIN(I,K) K = 1	
		11-20	Power to which toxic compound decays, n	K = 2	0.0
		21-30	Temperature coefficient for toxic decay constant, θ_{TC}	K = 3	1.0
			(Repeat cards Q9a and Q9b as necessary)		
Q9c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q10			DO Production by Phytoplankton		NONE
Q10a	20I4	1-4	Array of reach numbers		
		5-8			
		"			
		77-80			
Q10b	5F10.4	1-10	Proportionality constant for first cosine term, A_1, mg/ℓ day	SPRIN(I,K) K = 1	0.0
		11-20	Period, w, $\frac{1}{\text{hours}}$	K = 2	0.0
Q10b	5F10.4	21-30	Phase angle for first cosine term, ϕ_a, radians	K = 3	0.0
		31-40	Proportionality constant for second cosine term, A_2, mg/ℓ day	K = 4	0.0
		41-50	Phase angle for second cosine term, α, radians	K = 5	0.0
			(Repeat cards Q10a and Q10b as necessary)		

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q10c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q11			DO Production by Benthic Plants		
Q11a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			
Q11b	5F10.4	1-10	Proportionality constant for first cosine term, A_1^a, mg/ℓ day	APRIN(I,K) K = 1	0.0
		11-20	Period, w, $\frac{1}{\text{hours}}$	K = 2	0.0
		21-30	Phase angle for first cosine term, ϕ_a, radians	K = 3	0.0
		31-40	Proportionality constant for second cosine term, A_2^a mg/ℓ day	K = 4	0.0
		41-50	Phase angle for second cosine term, α_a, radians	K = 5	0.0
			(Repeat cards Q11a and Q11b as necessary)		
Q11c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q12			Reaeration Constants		
Q12a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			
Q12b	5F10.4	1-10	Multiplying factor for general model, r_1, $\frac{1}{\text{days}}$ (base e)	REAIN(I,K) K = 1	0.0
		11-20	Velocity exponent in general model, r_2	K = 2	0.0

Table B-6 (continued)

Card Group	Format	Column	Description	Variable	Default Values
Q12b	5F10.4	21-30	Depth exponent in general model, r_3	K = 3	0.0
		31-40	Temperature coefficient for reaeration coefficient, θ_k	K = 4	1.0
		41-50	Molecular diffusivity for O'Connor-Dobbins model, D_m, ft^2/hr	K = 5	0.0
			(Repeat cards Q12a and Q12b as necessary)		
Q12c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q13			Phosphorus Constants		
Q13a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			
Q13b	3F10.4	1-10	Rate constant from soluble-P to sediment-P, I_1, $\frac{1}{days}$	PHOIN(I,K) K = 1	0.0
		11-20	Rate constant from sediment to soluble-P, I_2, $\frac{1}{days}$	K = 2	0.0
		21-30	Rate constant from decaying organic-P to soluble-P, I_3, $\frac{1}{days}$	K = 3	0.0
			(Repeat cards Q13a and Q13b as necessary)		
Q13c	I4	1-4	Place 9999 in columns 1-4	NONE	NONE
Q14			Nitrogen Constants		
Q14a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q14b	3F10.4	1-10	Rate constant from ammonia to nitrite, J_1, $\frac{1}{day}$	TININ(I,K) K = 1	0.0
		11-20	If MODTIN = 1 rate constant from nitrite to nitrate, J_2, $\frac{1}{day}$	K = 2	0.0
			If MODTIN = 2 rate constant from ammonia to nitrate, J_2, $\frac{1}{day}$		
		21-30	Rate constant from decaying organic-N to ammonia, J_3, $\frac{1}{day}$	K = 3	0.0
			(Repeat cards Q14a and Q14b as necessary)		
Q14c	I4	1-4	Place 9999 in columns 1-4		
Q15			Algae Constants		
Q15a	20I4	1-4	Array of reach numbers		NONE
		5-8			
		"			
		77-80			
Q15b	8F10.4	1-10	Phytoplankton growth constant, F_1, $\frac{1}{day\ °C}$	ALGIN(I,K) K = 1	
		11-20	Photoperiod, f, day	K = 2	
		21-30	Extinction coefficient, k_e, $\frac{1}{m}$	K = 3	
		31-40	Incident light intensity, I_a, ℓy/day	K = 4	
		41-50	Saturated light intensity, I_s, ℓy/day	K = 5	
		51-60	Nitrogen constant, K_n, mg-N/ℓ	K = 6	
		61-70	Phosphorus constant, K_d, mg-D/ℓ	K = 7	

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q15b	8F10.4	71-80	Phytoplankton death constant, F_2, $\frac{1}{\text{day °C}}$	K = 8	
Q15c	8F10.4	1-10	Zooplankton grazing rate, Cg, $\frac{\ell}{\text{mg °C day}}$	K = 9	
		11-20	Conversion efficiency, A_{zp}	K = 10	
		21-30	Phytoplankton constant, K_{mp}, mg/ℓ	K = 11	
		31-40	Phytoplankton nitrogen/carbon ratio, A_{NP}	K = 12	
		41-50	Phytoplankton phosphorus/carbon ratio, A_{DP}	K = 13	
		51-60	Zooplankton nitrogen/carbon ratio, A_{NZ}	K = 14	
		61-70	Zooplankton phosphorus/carbon ratio, A_{DZ}	K = 15	
		71-80	Zooplankton death constant, F_3, $\frac{1}{\text{day °C}}$	K = 16	
Q15d	1F10.4	1-10	Zooplankton death constant, F_4, $\frac{1}{\text{days}}$	K = 17	
			(Repeat cards Q15a, Q15b, Q15c and Q15d as necessary)		
Q15e	I4	1-4	Place 9999 in columns 1-4		
Q16			Initial Concentration Options		
	I5	1-5	Input an integer to describe the method to be used to input initial concentrations = 1 Initial concentrations same for all nodes = 2 Initial concentrations uniform for each reach = 3 Initial concentrations specified for each node	IC	NONE
Q17			Initial concentration of parameters (Q17 cards are present only if IC = 1 in card group Q16 above)	C(J,K)	
Q17a	8F10.4	1-10	Benthic BOD, L_d, gm/m^2	K = 1	0.0
		11-20	Sediment phosphorus, D_2 mg/ℓ	K = 2	0.0
		21-30	Soluble phosphorus, D_1 mg/ℓ	K = 3	0.0
		31-40	Organic phosphorus, D_3, mg/ℓ	K = 4	0.0

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q17a	8F10.4	41-50	Carbonaceous BOD, L_c, mg/ℓ	K = 5	0.0
		51-60	Nitrogenous BOD, L_n, mg/ℓ	K = 6	0.0
		61-70	Refractory OC, C_R, mg/ℓ	K = 7	0.0
		71-80	Total OC, C_T, mg/ℓ	K = 8	0.0
Q17b	8F10.4	1-10	Ammonia nitrogen, C_1, mg/ℓ	K = 1	0.0
		11-20	Nitrite nitrogen, C_2, mg/ℓ	K = 2	0.0
		21-30	Nitrate nitrogen, C_3, mg/ℓ	K = 3	0.0
		31-40	Organic nitrogen, C_4, mg/ℓ	K = 4	0.0
		41-50	Toxic compound, T_c, mg/ℓ	K = 5	0.0
		51-60	Phytoplankton, P, mg/ℓ	K = 6	0.0
		61-70	Zooplankton, Z, mg/ℓ	K = 7	0.0
		71-80	Dissolved oxygen, DO, mg/ℓ	K = 8	0.0
Q18			Initial Concentration of Parameters (Q18 cards are present only if IC = 2 in card group Q16 above)		
Q18a	20I4	1-4	The array of reach numbers specifying the reaches that will have the initial conditions specified on cards Q18b and Q18c below.		NONE
		5-8			
		"			
		77-80			
Q18b			Same format and description as card Q17a above.		
Q18c			Same format and description as card Q17b above.		
			(Cards Q18a, Q18b and Q18c must be repeated until initial concentrations have been specified for every reach. To terminate the reading of Q18 cards, use card Q18d below.)		
Q18d	I4	1-4	Place 9999 in columns 1-4	NONE	NONE

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
Q19			Initial Concentration of Parameters (Q19 cards are present only if IC = 3 in card group Q16 above)		
Q19a			Same format and description as card Q17a above.		
Q19b			Same format and description as card Q17b above.		
			(Cards Q19a and Q19b are repeated for each node in the system.)		
Q20	I5	1-5	Total number of nodes where constant valued sources will be located. (The first NCSOUR sources will be associated with the first NCSOUR nodes listed on the Q5 cards.)	NCSOUR	NONE
Q21			Constant Values of Quality Parameter Sources (Card group Q21 is present only if NCSOUR >0 on card group Q20)	SOURIN(J,K)	NONE
Q21a			Same format and description as card Q17a above.		
Q21b			Same format and description as card Q17b above.		
			(Cards Q21a and Q21b are repeated NCSOUR times.)		
			Card Groups Q22, Q23, Q24 and Q27 below are used to specify inputs which can be time varying functions. The following NAMLIST option is used for these inputs. For each variable, the input format is one set of cards as follows: Title Card $CARD1 $END		
			Columns 20-80 of the title card is used as a free field to identify the data. If the word CONST is placed in columns 2-6 of the title card, then the $ CARD 1 and $ END cards will not be used. Instead, the number listed in columns 7-18 of the title card will be used as a constant value for the variable. If the input is to specify a time varying function (i.e., CONST does not appear in columns 2-6 of the title card), the $ CARD 1 must be present and have the following form: Column 2-6 $CARD1		

able B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
		Column 7-72	M=(number, an integer, of data points used), MIN=(number, an integer, giving minimum order of polynomial to be used to fit data), MAX=(number, an integer, giving maximum order of polynomial to be used to fit data), X=(a list of time, hrs, values separated by a comma), Y=(a list of the values, separated by a comma, of the function corresponding to the time values specified by X above).		
			The $CARD1 can consist of more than one card, but all data (including the separating commas) must be listed between columns 2-72 on each card. If MIN does not equal MAX on the $CARD1, the program will fit the data with a polynomial of each order in between. However, the MAX order fit will be used by the code to calculate the time varying values. MAX cannot exceed 4.		
Q22	NAMELIST Option		Values of Time Varying Quality Parameter Sources Card group Q22 is required only if NSOURC (see card Q2) > NCSOUR (see card Q21). For each source, 16 Q22 card sets must be made out, one set for each of the 16 quality parameters (in this case, the Y values would be the source strengths in lbs/day). The first 16 sets of Q22 cards correspond to the quality source at the (NCSOUR + 1)th node specified on card Q5 above, i.e., ISOP(NCSOUR + 1). The second 16 sets of Q22 cards correspond to the (NCSOUR + 2)th node specified on card Q5 above, etc.	SOURIN(J,K)	NONE
Q23			Temperature Card		
Q23a	NAMELIST Option		Values of the time varying temperatures (°C)	TEMP(I)	NONE
			(Card Q23a must be repeated NREACH times so that the temperature has been specified for all reaches.)		
Q24	NAMELIST Option		Dissolved Oxygen Values to be Used Below Controlled Nodes The Y values will specify the DO as a percent of saturation. If the DO is to be calculated for this node, a negative value should be entered. The	DO(J)	NONE

Table B-6 (continued)

Card Group	Format	Columns	Description	Variable	Default Values
			first set of Q24 cards will specify the DO concentration for the node downstream of node 1. The second set for the node downstream from node 2, and the last set for the node downstream from node NJGW (see card H1).		
Q25	I5	1-5	Total number of upstream nodes where constant values of parameter concentrations will be specified. (The first NUPSTR values will be associated with the first NUPSTR nodes listed on the Q3 cards.)	NCUPS	NONE
Q26			Constant Values of Quality Parameter Concentrations at Upstream Nodes (Card group Q26 is present only if NUPSTR >0 on card group Q25.)	UPSTR(J,K)	NONE
Q26a			Same format and description as card Q17a above.		
Q26b			Same format and description as card Q17b above.		
			(Cards Q26a and Q26b are repeated NUPSTR times.)		
Q27	NAMELIST Option		Values of Time Varying Quality Parameters at Upstream Nodes Card group Q27 is required only if NUPSTR (see card group Q2) > NCUPS (see card group Q25). The Y values specify the concentration of the quality parameter at the upstream node in mg/ℓ. For each upstream node, 16 sets of Q25 cards must be specified, one for each quality parameter. The first set corresponds to the first node listed on card Q3; the second set to the second node listed on card Q3, etc.	UPSTR(J,K)	NONE
Q28	5A4	1-20	Place a series of asterisks in columns 1-20 to terminate reading of the quality input deck.		

```
CARD GROUP                                                                                  REMARKS

Q1          CALIBRATION OF EXPLORE I  ON WILLAMETTE RIVER FROM SALEM TO PORTLAND SEPT 67
Q2            0    1    2    1    1    1    1      0.95      01.0   12    6   10    7    0
Q3           39   53   56   63   51   32
Q4            1    8
              2   17
             18   21
             22   32
             57   63
             54   56
             52   53
             33   39
             40   45
             46   51
Q5           35   59    9   41   49   17    8
Q6            1                                                                             BOD constants
                 0.1      0.15        0.     1.047        0.        0.
              2
                 .12        0.        0.     1.047       .08     1.047
              3
                  .3       1.0        0.     1.047       .08     1.047
              4
                  .3        0.        0.     1.047       .08     1.047
              9    5
                 0.1        0.        0.     1.047        0.        0.
              6    7    8   10
                  .3        0.        0.     1.047        0.        0.
          9999
Q7            1    3                                                                        Benthic BOD constants
                 .05     1.047
              2    4    5    6    7    8    9   10
                  0.        0.
          9999
Q8            1    2    3    4    5    6    7    8    9   10                                TOC constants
                  0.        0.        0.        0.        0.        0.
          9999
Q9            1    2    3    4    5    6    7    8    9   10                                Toxic constants
                  0.        0.        0.
          9999
Q10           1    2    3    4    5    6    7    8    9   10                                (P-R) for suspended algae
                  0.        0.        0.        0.        0.
          9999
Q11           1    2    3    4    5    6    7    8    9   10                                (P-R) for benthic algae
                  0.        0.        0.        0.        0.
          9999
Q12           1    2    3    4    5    6    7    8    9   10                                Reaeration constants
                 4.0       0.8      1.67    1.0240        0.
          9999
Q13           1    2    3    4                                                              Phosphorus constants
                0.08        0.        0.
              5    6    7    8    9   10
                  0.        0.        0.
          9999
```

FIGURE B-11. LISTING OF INPUT DATA DECK FOR QUALITY CODE

```
CARD GROUP                                                                              REMARKS

Q14          1                                                                          Nitrogen constants
               .09       2.        1.
             2   3   4
               .09       2.0       0.
             5   6   7   8   9   10
               0.        0.        0.
            9999
Q15          2   3   4   5   6   7   8   9   10                                          Algae constants
               0.        1.        1.        1.        1.        1.        1.        0.
               0.        1.        1.        1.        1.        1.        1.        0.
               0.
             1
               0.2       0.6       2.        5.        30.       0.0250    0.0025    0.0050
               0.13      0.6       60.       0.17      0.017     0.01      0.001     0.003
               0.015
Q16         9999                                                                        Initial conditions
              2
Q18          1                                                                          Constant for each reach
               75.0      0.        0.05      0.        2.0       1.0       0.        0.0
               0.3       0.        0.40      0.        0.0       1.0       0.1       4.0
             2
               0.0       0.        0.05      0.        1.0       1.0       0.        0.0
               0.3       0.        0.40      0.        0.0       0.0       0.        6.0
             3
               115.      0.        0.05      0.        1.5       1.0       0.        0.0
               0.3       0.        0.40      0.        0.5       0.0       0.        6.0
             4
               0.0       0.        0.05      0.        2.5       1.0       0.        0.0
               0.3       0.        0.40      0.        0.5       0.0       0.        6.5
             5
               0.0       0.        0.03      0.        4.5       0.0       0.        0.0
               0.4       0.        0.00      0.        0.5       0.0       0.        7.0
             6
               0.0       0.        0.40      0.        4.5       0.0       0.        0.0
               0.3       0.        0.00      0.        0.5       0.0       0.        7.0
             7
               0.0       0.        0.10      0.        1.5       0.0       0.        0.0
               0.3       0.        0.00      0.        0.5       0.0       0.        7.0
             8
               0.0       0.        0.00      0.        0.5       0.0       0.        0.0
               0.0       0.        0.00      0.        0.5       0.0       0.        7.0
             9
               0.0       0.        0.20      0.        2.5       0.0       0.        0.0
               0.4       0.        0.00      0.        0.5       0.0       0.        7.0
            10
               0.0       0.        0.20      0.        2.5       0.0       0.        0.0
               0.4       0.        0.00      0.        0.5       0.0       0.        7.0
            9999
Q20           5                                                                         Five constant sources
Q21            0.0       0.        650.      0.        2600.     0.0       0.        0.0
               1200.     0.        0         0.        00.       0.0       0.        0.0
               0.0       0.        0.        0.        160.      0.0       0.        0.0
```

FIGURE B-11. (continued)

CARD GROUP | *REMARKS*

Q22

```
       0.0       0.        0.        0.       00.       0.0       0.      600.
       0.0       0.        0.        0.       00.       0.0       0.       00.
       0.0       0.        0         0.       00.       0.        0.       00.
        0.       0.       15.        0.      250.       0.        0.        0.
       10.       0.        0.        0.        0.       0.        0.        0.
        0.       0.        0         0.      250.       0.        0.        0.
       10.       0.        0         0.        0.       0.        0.        0.
 CONST            0.       BEN          SOURCE - NODE 17  NEWBERG
 CONST            0.       SED PHOS     SOURCE - NODE 17  NEWBERG
 CONST            0.       SOL PHOS     SOURCE - NODE 17  NEWBERG
 CONST            0.       ORG PHOS     SOURCE - NODE 17  NEWBERG
                           CAR BOD      SOURCE - NODE 17  NEWBERG
$CARD1  M=3, MIN=2, MAX=2, X=0., 192., 360., Y= 12200., 14600., 14700.
$END
 CONST            0.       NIT BOD      SOURCE - NODE 17  NEWBERG
 CONST            0.       REF OC       SOURCE - NODE 17  NEWBERG
 CONST            0.       TOC          SOURCE - NODE 17  NEWBERG
 CONST            0.       NH3          SOURCE - NODE 17  NEWBERG
 CONST            0.       NO2          SOURCE - NODE 17  NEWBERG
 CONST            0.       NO3          SOURCE - NODE 17  NEWBERG
 CONST            0.       ORG N        SOURCE - NODE 17  NEWBERG
 CONST            0.       TOXIC        SOURCE - NODE 17  NEWBERG
 CONST            0.       PHYTO        SOURCE - NODE 17  NEWBERG
 CONST            0.       ZOO          SOURCE - NODE 17  NEWBERG
 CONST            0.       DO           SOURCE - NODE 17  NEWBERG
 CONST            0.       BEN          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       SED PHOS     SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       SOL PHOS     SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       ORG PHOS     SOURCE - NODE 8  WILLAMETTE FALLS
                           CAR BOD      SOURCE - NODE 8  WILLAMETTE FALLS
$CARD1  M=3, MIN=2, MAX=2, X=0., 192., 360., Y= 49400., 40600., 47100.
$END
```

Two time dependent sources

Q23

```
 CONST            0.       NIT BOD      SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       REF OC       SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       TOC          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       NH3          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       NO2          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       NO3          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       ORG N        SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       TOXIC        SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       PHYTO        SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       ZOO          SOURCE - NODE 8  WILLAMETTE FALLS
 CONST            0.       DO           SOURCE - NODE 8  WILLAMETTE FALLS
                           TEMPERATURE REACH 1  9/1 - 9/15  DATA      WMS
$CARD1 M=7, MIN=3, MAX=3, X= 0., 96., 168., 216., 264., 312., 360.,
          Y= 21.5, 21.5, 21.5, 21.0, 20.0, 19.3, 19.0
$END

                           TEMPERATURE REACH 2  9/1 - 9/15  DATA      WMS
$CARD1 M=8, MIN=3, MAX=3, X= 0., 48., 96., 168., 216., 264., 312.,360.,
          Y= 21.5, 21.5, 21.5, 21.1, 20.5, 19.5, 18.7, 18.0
$END

                           TEMPERATURE REACH 3  9/1 - 9/15  DATA      WMS
```

Temperature must be specified for each reach

FIGURE B-11. (continued)

```
CARD GROUP                                                                                    REMARKS

            $CARD1 M=9, MIN=3, MAX=3, X=0. , 48. , 96. , 144. , 192. , 240. , 288. , 324. , 360. ,
                      Y= 21 5, 21 5, 21. 5, 20. 5, 19. 7, 18. 8, 18. 0, 18. 0, 18. 0
            $END
                                  TEMPERATURE REACH 4  9/1 - 9/15  DATA      WMS
            $CARD1 M=9, MIN=3, MAX=3, X=0. , 48. , 96. , 144. , 192. , 240. , 288. , 324. , 360. ,
                      Y= 21. 5, 21 5, 21. 5, 20. 5, 19. 7, 18. 8, 18. 0, 18. 0, 18. 0
            $END
            CONST        23.       TEMPERATURE REACH  5    8/2 DATA    YAMHILL
            CONST        26.       TEMPERATURE REACH  6    8/1 DATA    PUDDING
            CONST        25.       TEMPERATURE REACH  7    8/1 DATA    MOLLALA
            CONST        21.       TEMPERATURE REACH  8    8/1 DATA    CLACKAMAS
            CONST        19.       TEMPERATURE REACH  9    9/5 DATA    TUALATIN
            CONST        19.       TEMPERATURE REACH 10    9/5 DATA    TUALATIN
Q24         CONST        -1.           DO BELOW NODE 1                                  Dissolved oxygen below
            CONST        0. 88     DO AT NODE  8   BELOW WILLAMETTE FALLS               controlled nodes
Q25           5
Q26               0.        0.        0.        0.        0.        0.        0.        0. Five constant upstream nodes
                  0.        0.        0.        0.        0.        0.        0.        9.
                  0.        0.       0. 14      0.       0. 9       0.        0.        0.
                0. 37       0.       0. 01      0.        0.        0.        0.       9. 2
                  0.        0.       0. 41      0.       4. 1       0.        0.        0.
                0. 35       0.       0. 01      0.        0.        0.        0.      15. 6
                  0.        0.       0. 35      0.       4. 0       0.        0.        0.
                0. 27       0.       0. 01      0.        0.        0.        0.      10. 0
                  0.        0.       0. 23      0.       2. 1       0.        0.        0.
                0. 47       0.       . 053      0.        0.        0.        0.       5. 3
Q27         CONST         0.       BEN          WMS-SALEM                                One time varying upstream
            CONST         0.       SED PHOS     WMS-SALEM                                node
            CONST        0. 06     SOL PHOS     WMS-SALEM
            CONST         0.       ORG PHOS     WMS-SALEM
                                   CAR BOD      WMS-SALEM
            $CARD1  M=3,  MIN=2,  MAX=2,  X= 0. ,  120. ,  288. ,        Y= 2. 15,  1. 80,  2. 0
            $END
            CONST        1. 67     NIT BOD      WMS-SALEM
            CONST         0.       REF OC       WMS-SALEM
            CONST         0.       TOC          WMS-SALEM
            CONST        0. 37     NH3          WMS-SALEM
            CONST         0.       N02          WMS-SALEM
            CONST        0. 31     N03          WMS-SALEM
            CONST         0.       ORG N        WMS-SALEM
            CONST         1.       TOXIC        WMS-SALEM
            CONST         0.       PHYTO        WMS-SALEM
            CONST         0.       ZOO          WMS-SALEM
                                   DO           WMS-SALEM
            $CARD1  M=4,  MIN=2,  MAX=2,  X=0. ,  120. ,  240. ,  360. ,  Y= 6. 9,  7. 10,  7. 20,
                                   7. 30
Q28         $END
            ****************************************************************************************
```

FIGURE B-11. (continued)

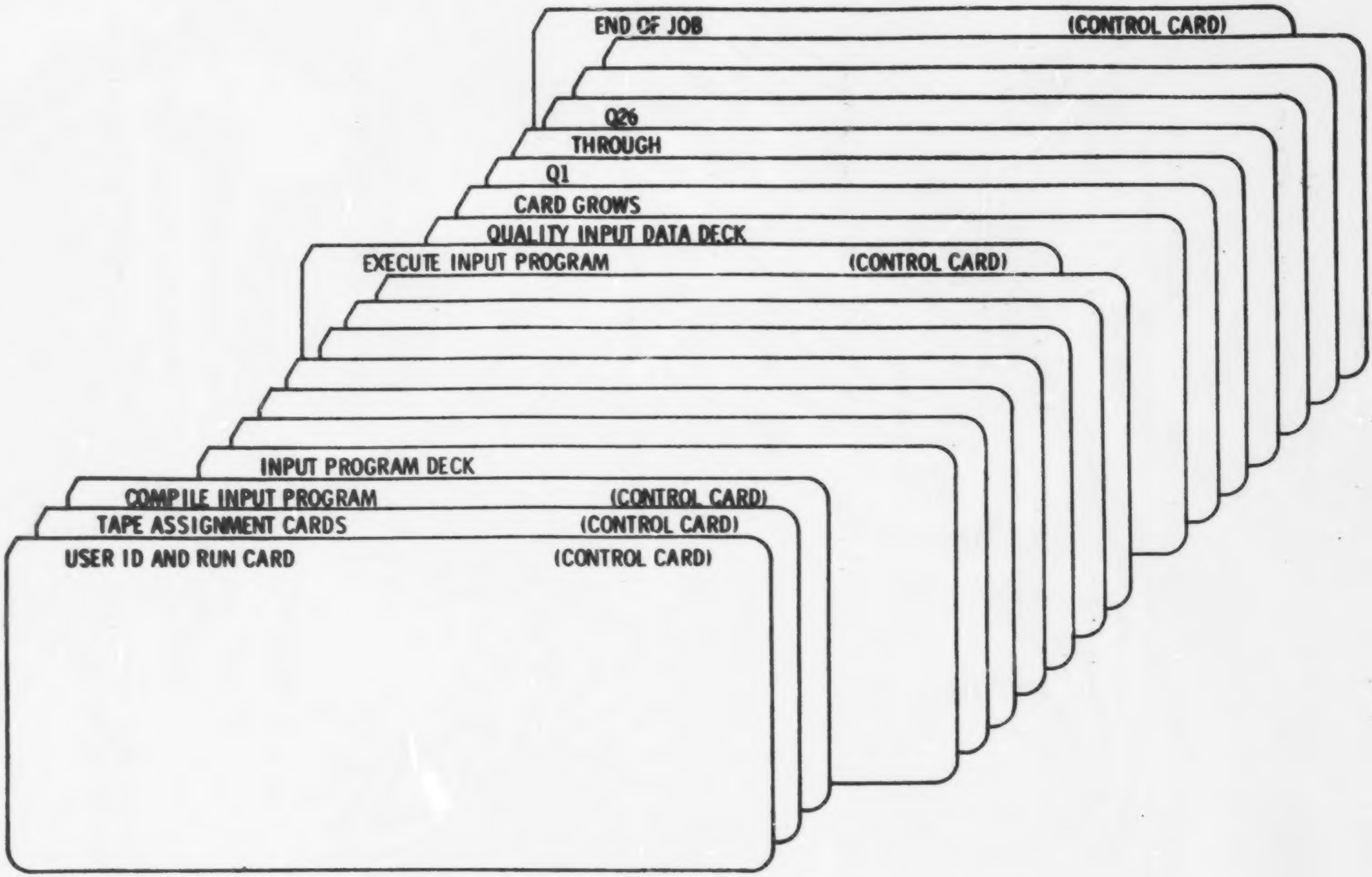

END OF JOB
(CONTROL CARD)
Q26
THROUGH
Q1
CARD GROWS
QUALITY INPUT DATA DECK
EXECUTE INPUT PROGRAM
(CONTROL CARD)
INPUT PROGRAM DECK
COMPILE INPUT PROGRAM
(CONTROL CARD)
TAPE ASSIGNMENT CARDS
(CONTROL CARD)
USER ID AND RUN CARD
(CONTROL CARD)

FIGURE B-12. CONSTRUCTION OF CARD DECK FOR QUALITY INPUT CODE

- reaction constants input for each reach;
- initial conditions for each node; and
- values of sources, temperatures, upstream node concentrations, and dissolved oxygen specifications.

The output is self explanatory.

The results of the quality calculations are written out at the end of each time step. After the calculations for an entire time period have been completed the calculated data is searched and the information requested by the user, generally the following data, is printed out: the parameter concentrations calculated at each time step and node specified by the user; the node temperature; the reaeration constant corrected for temperature; and the net contribution to the dissolved oxygen equation from photosynthesis and respiration. At the top of each page the day and hour are printed, along with the corresponding tidal and quality cycle numbers.

The following options are available to the user in requesting output:

- printout concentrations for every node;
- printout concentrations for the particular nodes specified, in the order listed;
- punch cards of concentrations in format for use in case restart.

In addition, the user can specify the particular times at which output is to be printed or punched. The second option listed above allows print out of information along the length of one tributary at a time in the order the nodes appear along that tributary, even if they are not in numerical order.

Table B-7 gives the input instructions for specifying the output. Execution of the quality code requires three tape assignments:

Unit 2 - tape containing hydraulic data

Unit 3 - tape for writing results of input code calculations

Unit 7 - tape for writing results of quality calculations

Figure B-13 shows the construction of the data deck for execution of the quality calculation code.

TABLE B-7

INPUT FORMAT FOR PRINTOUT OF RESULTS

CARD	FORMAT	COLUMNS	DESCRIPTION	VARIABLE	DEFAULT VALUES
Q01	20A4	1-80	Title (this title will appear at the top of each page of the output)		BLANK
Q02	I10	1-10	The first day for output		NQSWRT
		11-20	The first hour in the first day for output		1.0
		21-30	The last day for output		NQSWRT
		31-40	The last hour in the last day for output		1.0
Q03	2I5	1-5	0 for no cards punched 1 for cards punched		None
		6-10	0 for printout of nodes specified on cards 04 and 05 1 for printout of all nodes in numerical order		None
			(Card Q04 and Q05 are required only if column 10 is zero on card Q03 above)		
Q04	I10	1-10	Number of nodes to be printed out		None
Q05	20I4	1-4	Array of node number in order to be printed out		None
		5-8	" " " " "		
		"	" " " " "		
		"	" " " " "		
		77-80			

Repeat cards Q01 through Q05 as many times as desired to obtain all time points of interest

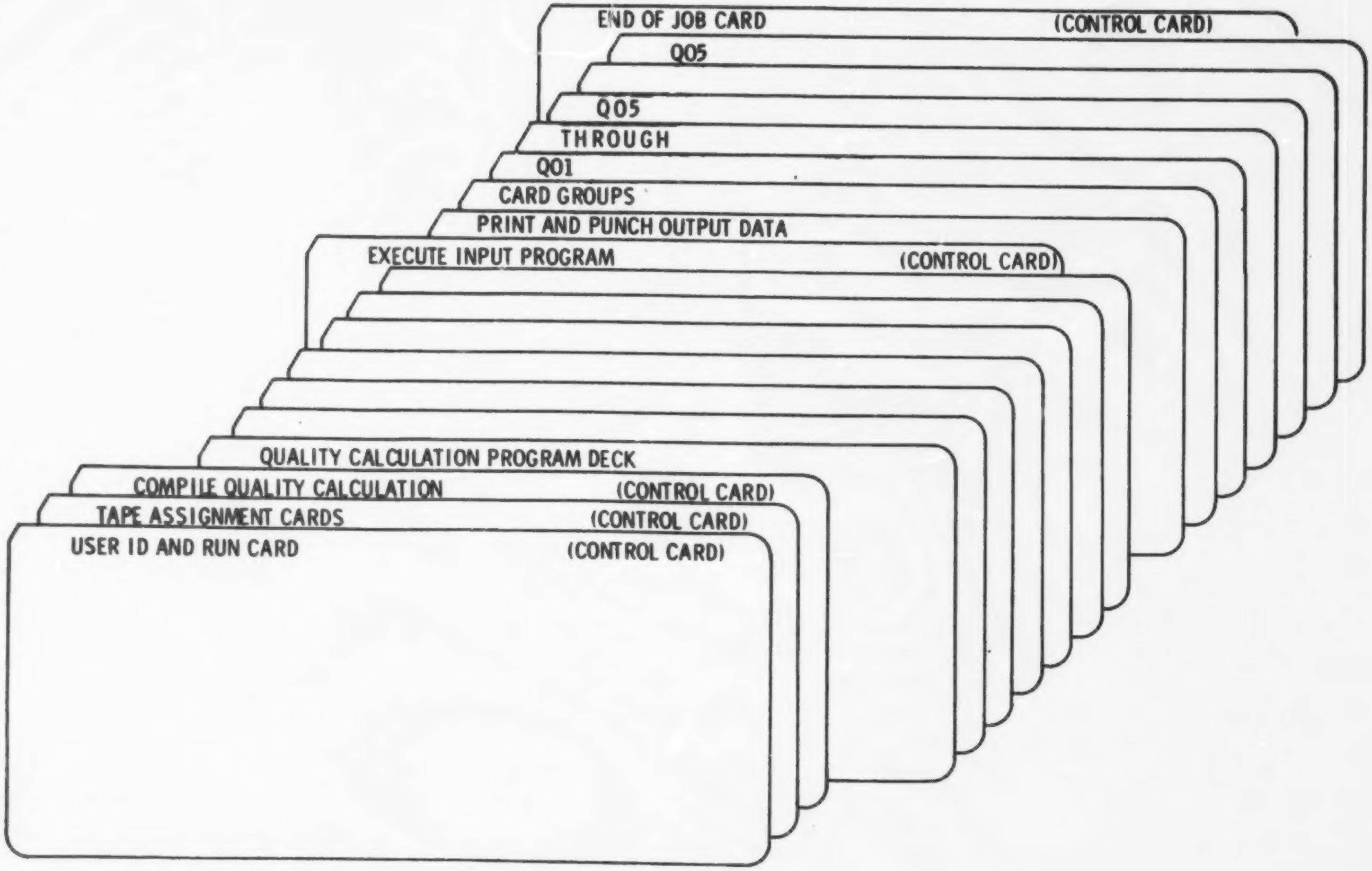

END OF JOB CARD
(CONTROL CARD)
Q05
Q05
THROUGH
Q01
CARD GROUPS
PRINT AND PUNCH OUTPUT DATA
EXECUTE INPUT PROGRAM
(CONTROL CARD)
QUALITY CALCULATION PROGRAM DECK
COMPILE QUALITY CALCULATION
(CONTROL CARD)
TAPE ASSIGNMENT CARDS
(CONTROL CARD)
USER ID AND RUN CARD
(CONTROL CARD)

FIGURE B-13. CONSTRUCTION OF CARD DECK FOR QUALITY CALCULATION CODE

Since the output of the quality program is saved on magnetic tape, not all desired information must be printed out at the time the code is run. By use of the reprint code additional printouts can be obtained long after the calculations are performed. Input instructions for this code are given in Table B-8. The construction of the reprint data deck is shown in Figure B-14 and Figure B-15 is an example of the output.

TABLE B-8

INPUT FORMAT FOR REPRINT

CARD	FORMAT	COLUMNS	DESCRIPTION	VARIABLE	DEFAULT VALUES
R1	4I5	1-5	Number of nodes NJ		None
		6-10	Beginning of hydraulic writeout NQSWRT		
		11-15	Total number of quality cycles written out NQTCYC		
		16-20	Number of quality cycles per tidal cycle NQCYC		
	2F10.0	21-30	Number of hours per tidal cycle PERIOD		
		31-40	Length of quality cycle in seconds DELTQ		
R2			Consists of the cards Q01 through Q04 discussed in Table B-7		

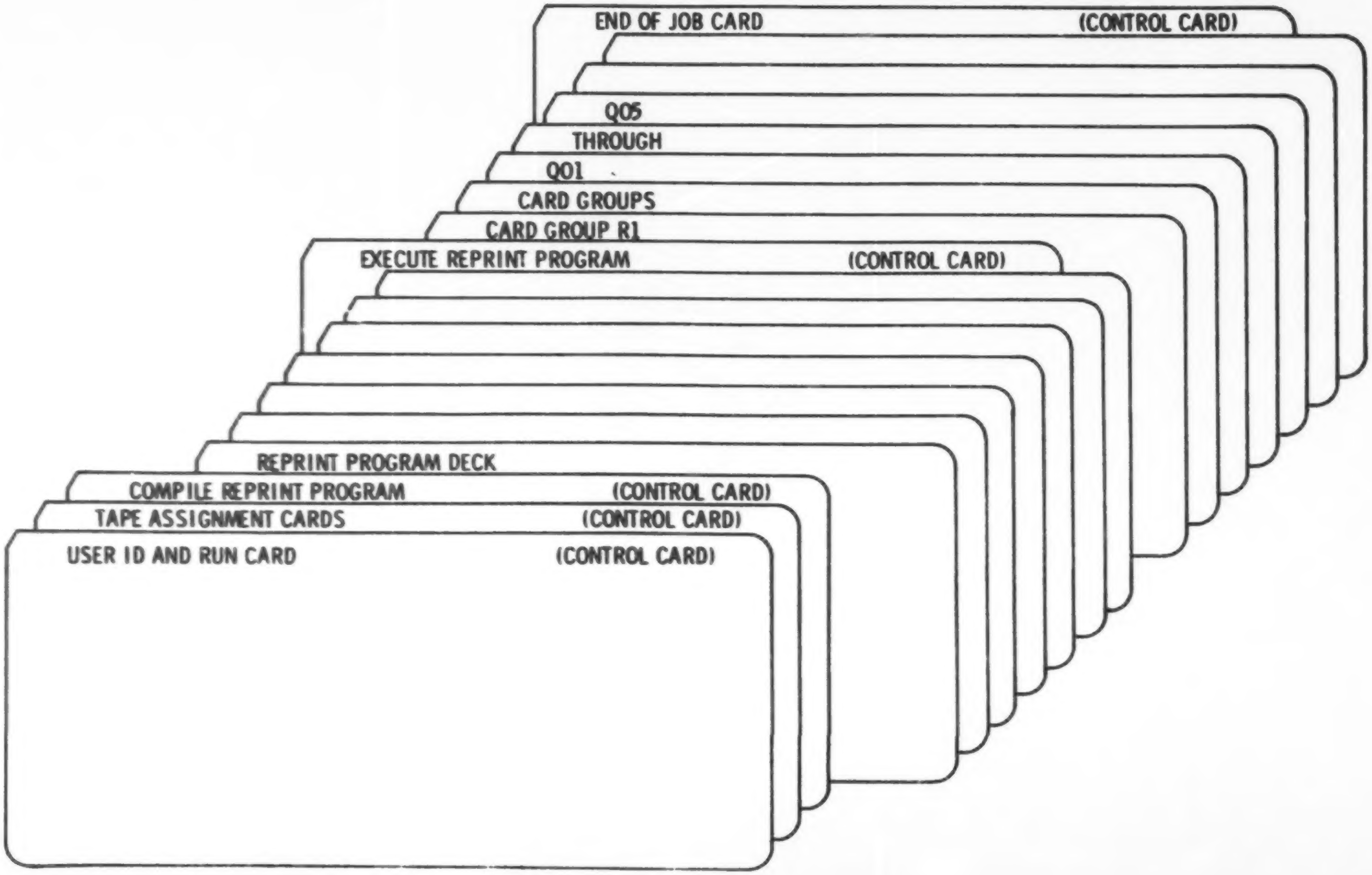

END OF JOB CARD (CONTROL CARD)
Q05
THROUGH
Q01
CARD GROUPS
CARD GROUP R1
EXECUTE REPRINT PROGRAM (CONTROL CARD)
REPRINT PROGRAM DECK
COMPILE REPRINT PROGRAM (CONTROL CARD)
TAPE ASSIGNMENT CARDS (CONTROL CARD)
USER ID AND RUN CARD (CONTROL CARD)

FIGURE B-14. CONSTRUCTION OF CARD DECK FOR REPRINT CODE

```
      EXPLORE I  VERIFICATION ON WILLAMETTE FROM SALEM TO PORTLAND SEPT 67      3      BATTELLE NORTHWEST, RICHLAND, WASHINGTON
                                                                                          EXPLORE-1 CODE QUALITY MODEL
                        DAY   13  HOUR  -.50                        TIDAL CYCLE   12 QUALITY CYCLE   12
  NODE      TEMP.( C )       FEN BOD   SFD PHOS  SOL PHOS  ORG PHOS  CAR BOD   NIT BOD   REF OC      TOC       NH3       NO2
                             NO3       ORG N     TOXIC     PHYTO     ZOO                                 DO        REA       P-R

    1         19.84          5.274+01  5.482-02  6.292-02  4.212-06  7.901-01  7.454-01  0.000       0.000     2.011-01  9.343-03
                             3.168-01  1.166-05  6.401-01  7.494-04  6.817-05                     6.671+00  1.600-02  0.000
    2         19.24          0.000     4.362-02  4.575-02  0.000     7.704-01  1.137+00  0.000       0.000     2.476-01  1.160-02
                             4.056-01  0.000     9.665-01  1.145-03  1.145-04                     6.355+00  6.749-03  0.000
    3         19.64          5.078+01  6.055-02  6.925-02  2.915-06  9.474-01  7.922-01  0.000       0.000     2.275-01  1.019-02
                             3.242-01  1.081-05  6.802-01  7.703-04  7.063-05                     7.272+00  2.290-02  0.000
    4         19.64          4.903+01  6.491-02  7.239-02  2.003-06  1.061+00  7.996-01  0.000       0.000     2.340-01  1.044-02
                             3.154-01  9.520-06  6.852-01  7.815-04  7.316-05                     7.547+00  2.778-02  0.000
    5         19.84          5.309+01  6.609-02  7.466-02  1.428-06  1.194+00  8.014-01  0.000       0.000     2.423-01  1.035-02
                             3.070-01  7.994-06  6.852-01  7.893-04  7.533-05                     7.761+00  2.277-02  0.000
    6         19.64          5.479+01  7.066-02  7.671-02  9.499-07  1.300+00  8.016-01  0.000       0.000     2.496-01  9.962-03
                             2.945-01  6.134-06  6.840-01  7.998-04  7.712-05                     7.920+00  3.303-02  0.000
    7         19.64          4.902+01  7.371-02  7.659-02  4.513-07  1.438+00  8.194-01  0.000       0.000     2.556-01  9.220-03
                             2.382-01  3.539-06  6.977-01  8.285-04  8.077-05                     8.075+00  9.712-02  0.000
    8         19.64          4.943+01  4.323-02  4.529-02  2.528-07  1.806+00  1.136+00  0.000       0.000     2.448-01  1.148-02
                             4.065-01  2.188-06  9.666-01  1.149-03  1.134-04                     7.965+00  9.712-02  0.000
    9         19.24          0.000     4.520-02  4.758-02  0.000     8.222-01  1.184+00  0.000       0.000     2.587-01  1.205-02
                             3.941-01  0.000     9.664-01  1.145-03  1.145-04                     6.466+00  9.723-03  0.000
   10         19.24          0.000     4.525-02  4.763-02  0.000     8.445-01  1.219+00  0.000       0.000     2.648-01  1.234-02
                             3.876-01  0.000     9.692-01  0.000     0.000                        6.528+00  1.327-02  0.000
   11         19.24          0.000     4.680-02  4.931-02  0.000     8.973-01  1.264+00  0.000       0.000     2.755-01  1.272-02
                             3.765-01  0.000     9.693-01  0.000     0.000                        6.625+00  1.556-02  0.000
   12         19.24          0.000     4.432-02  4.676-02  0.000     9.076-01  1.305+00  0.000       0.000     2.794-01  1.304-02
                             3.757-01  0.000     9.835-01  0.000     0.000                        6.647+00  1.324-02  0.000
   13         19.24          0.000     4.536-02  4.796-02  0.000     9.492-01  1.339+00  0.000       0.000     2.875-01  1.334-02
                             3.683-01  0.000     9.839-01  0.000     0.000                        6.719+00  1.121-02  0.000
   14         19.24          0.000     4.703-02  4.978-02  0.000     1.014+00  1.391+00  0.000       0.000     2.998-01  1.373-02
                             3.561-01  0.000     9.845-01  0.000     0.000                        6.833+00  1.391-02  0.000
   15         19.24          0.000     4.849-02  5.132-02  0.000     1.071+00  1.433+00  0.000       0.000     3.101-01  1.390-02
                             3.460-01  0.000     9.851-01  0.000     0.000                        6.927+00  1.546-02  0.000
   16         19.24          0.000     4.984-02  5.271-02  0.000     1.124+00  1.472+00  0.000       0.000     3.196-01  1.385-02
                             3.369-01  0.000     9.856-01  0.000     0.000                        7.010+00  1.864-02  0.000
   17         19.24          0.000     5.160-02  5.448-02  0.000     1.193+00  1.521+00  0.000       0.000     3.316-01  1.338-02
                             3.258-01  0.000     9.862-01  0.000     0.000                        7.113+00  3.029-02  0.000
   18         18.13          1.238+02  5.250-02  5.535-02  0.000     1.604+00  1.545+00  0.000       0.000     3.376-01  1.275-02
                             2.207-01  0.000     9.865-01  0.000     0.000                        7.159+00  5.353-02  0.000
   19         18.13          1.119+02  5.326-02  5.608-02  0.000     1.292+00  1.564+00  0.000       0.000     3.425-01  1.194-02
                             3.168-01  0.000     9.870-01  0.000     0.000                        7.353+00  1.510-01  0.000
   20         18.13          9.105+01  5.361-02  5.635-02  0.000     1.434+00  1.575+00  0.000       0.000     3.453-01  1.136-02
                             3.153-01  0.000     9.881-01  0.000     0.000                        7.470+00  4.309-01  0.000
```

FIGURE B-15. SAMPLE OUTPUT OF QUALITY CODE

```
EXPLORE I  VERIFICATION ON WILLAMETTE FROM SALEM TO PORTLAND SEPT 67      3      BATTELLE NORTHWEST, RICHLAND, WASHINGTON
                                                                                   EXPLORE-1 CODE QUALITY MODEL
                          DAY   13  HOUR  -.50                    TIDAL CYCLE   12 QUALITY CYCLE   12
NODE      TEMP.( C )      BEN BOD   SED PHOS  SOL PHOS  ORG PHOS  CAR BOD   NIT BOD   REF OC      TOC       NH3       NO2
                          NO3       ORG N     TOXIC     PHYTO     ZOO
                                                                                                     DO        REA       P-R
 21       18.13           9.305+01  5.390-02  5.663-02  0.000     1.543+00  1.582+00  0.000       0.000     3.472-01  1.087-02
                          3.141-01  0.000     9.886-01  0.000     0.000
                                                                                                     7.563+00  6.775-01  0.000
 22       18.13           0.000     5.424-02  5.695-02  0.000     1.678+00  1.590+00  0.000       0.000     3.494-01  1.024-02
                          3.129-01  0.000     9.891-01  0.000     0.000
                                                                                                     7.647+00  7.480-01  0.000
 23       18.13           0.000     5.454-02  5.723-02  0.000     1.708+00  1.598+00  0.000       0.000     3.513-01  9.597-03
                          3.119-01  0.000     9.895-01  0.000     0.000
                                                                                                     7.611+00  7.361-01  0.000
 24       18.13           0.000     5.483-02  5.750-02  0.000     1.739+00  1.605+00  0.000       0.000     3.532-01  8.889-03
                          3.110-01  0.000     9.899-01  0.000     0.000
                                                                                                     7.575+00  7.670-01  0.000
 25       18.13           0.000     5.507-02  5.773-02  0.000     1.764+00  1.610+00  0.000       0.000     3.547-01  8.247-03
                          3.104-01  0.000     9.902-01  0.000     0.000
                                                                                                     7.544+00  6.293-01  0.000
 26       18.13           0.000     5.536-02  5.800-02  0.000     1.795+00  1.617+00  0.000       0.000     3.565-01  7.364-03
                          3.096-01  0.000     9.905-01  0.000     0.000
                                                                                                     7.517+00  3.997-01  0.000
 27       18.13           0.000     5.563-02  5.824-02  0.000     1.823+00  1.624+00  0.000       0.000     3.582-01  6.519-03
                          3.091-01  0.000     9.910-01  0.000     0.000
                                                                                                     7.515+00  7.080-01  0.000
 28       18.13           0.000     5.586-02  5.846-02  0.000     1.848+00  1.629+00  0.000       0.000     3.597-01  5.684-03
                          3.087-01  0.000     9.914-01  0.000     0.000
                                                                                                     7.490+00  1.206+00  0.000
 29       18.13           0.000     5.610-02  5.868-02  0.000     1.873+00  1.635+00  0.000       0.000     3.612-01  4.771-03
                          3.084-01  0.000     9.918-01  0.000     0.000
                                                                                                     7.423+00  9.635-01  0.000
 30       18.13           0.000     5.646-02  5.900-02  0.000     1.912+00  1.643+00  0.000       0.000     3.634-01  3.252-03
                          3.080-01  0.000     9.922-01  0.000     0.000
                                                                                                     7.347+00  8.525-01  0.000
 31       18.13           0.000     5.678-02  5.930-02  0.000     1.946+00  1.651+00  0.000       0.000     3.654-01  1.790-03
                          3.079-01  0.000     9.929-01  0.000     0.000
                                                                                                     7.294+00  1.076+00  0.000
 32       18.13           0.000     0.000     6.000-02  0.000     1.996+00  1.670+00  0.000       0.000     3.700-01  0.000
                          3.100-01  0.000     1.000+00  0.000     0.000
                                                                                                     7.252+00  1.076+00  0.000
 33       21.00           0.000     0.000     1.596-01  0.000     5.700-01  0.000     0.000       0.000     2.947-01  0.000
                          0.000     0.000     6.206-35  0.000     0.000
                                                                                                     8.778+00  2.107+00  0.000
 34       21.00           0.000     0.000     1.651-01  0.000     6.163-01  0.000     0.000       0.000     3.048-01  0.000
                          0.000     0.000     5.469-35  0.000     0.000
                                                                                                     8.783+00  4.771+00  0.000
 35       21.00           0.000     0.000     1.733-01  0.000     6.064-01  0.000     0.000       0.000     3.199-01  0.000
                          0.000     0.000     4.323-35  0.000     0.000
                                                                                                     8.774+00  5.848+00  0.000
 36       21.00           0.000     0.000     0.000     0.000     1.197-35  0.000     0.000       0.000     0.000     0.000
                          0.000     0.000     3.200-35  0.000     0.000
                                                                                                     6.808+00  6.078+00  0.000
 37       21.00           0.000     0.000     0.000     0.000     5.476-36  0.000     0.000       0.000     0.000     0.000
                          0.000     0.000     1.651-35  0.000     0.000
                                                                                                     8.831+00  6.874+00  0.000
 38       21.00           0.000     0.000     0.000     0.000     1.572-36  0.000     0.000       0.000     0.000     0.000
                          0.000     0.000     7.467-36  0.000     0.000
                                                                                                     8.921+00  8.333+00  0.000
 39       21.00           0.000     0.000     0.000     0.000     0.000     0.000     0.000       0.000     0.000     0.000
                          0.000     0.000     0.000     0.000     0.000
                                                                                                     9.000+00  6.333+00  0.000
 40       19.00           0.000     0.000     4.184-01  0.000     5.158+00  0.000     0.000       0.000     6.649-01  0.000
                          3.290-02  0.000     6.889-02  0.000     0.000
                                                                                                     9.190+00  2.915+01  0.000
```

FIGURE B-15. (continued)

```
EXPLORE I VERIFICATION ON WILLAMETTE FROM SALEM TO PORTLAND SEPT 67     3      BATTELLE NORTHWEST, RICHLAND, WASHINGTON
                                                                              EXPLORE-1 CODE QUALITY MODEL
                   DAY   13  HOUR  -.50                      TIDAL CYCLE   12 QUALITY CYCLE   12
NODE,    TEMP.( C )     PEN BOD  SED PHOS  SOL PHOS  ORG PHOS   CAR BOD  NIT BOD   REF OC       TOC        NH3        NO2
                        NO3      ORG N     TOXIC     PHYTO      ZOO                                    DO         REA        P-R
  41       19.00        0.000    0.000     4.250-01  0.000      5.481+00  0.000    0.000       0.000     6.753-01   0.000
                        3.436-02 0.000     5.532-02  0.000      0.000                               9.186+00   4.405+01   0.000
  42       19.00        0.000    0.000     1.794-01  0.000      1.036+00  0.000    0.000       0.000     5.350-01   0.000
                        3.751-02 0.000     4.166-02  0.000      0.000                               9.193+00   2.183+01   0.000
  43       19.00        0.000    0.000     1.869-01  0.000      1.655+00  0.000    0.000       0.000     5.600-01   0.000
                        4.043-02 0.000     2.196-02  0.000      0.000                               9.181+00   1.389+01   0.000
  44       19.00        0.000    0.000     1.931-01  0.000      2.112+00  0.000    0.000       0.000     5.843-01   0.000
                        4.302-02 0.000     9.359-03  0.000      0.000                               9.192+00   1.213+01   0.000
  45       19.00        0.000    0.000     1.933-01  0.000      2.308+00  0.000    0.000       0.000     5.860-01   0.000
                        4.422-02 0.000     3.352-03  0.000      0.000                               9.181+00   1.135+01   0.000
  46       19.00        0.000    0.000     1.947-01  0.000      2.541+00  0.000    0.000       0.000     5.910-01   0.000
                        4.479-02 0.000     9.521-04  0.000      0.000                               9.130+00   1.073+01   0.000
  47       19.00        0.000    0.000     1.963-01  0.000      3.272+00  0.000    0.000       0.000     5.957-01   0.000
                        4.520-02 0.000     2.008-04  0.000      0.000                               9.057+00   9.776+00   0.000
  48       19.00        0.000    0.000     2.121-01  0.000      4.571+00  0.000    0.000       0.000     6.435-01   0.000
                        4.867-02 0.000     1.478-05  0.000      0.000                               9.037+00   8.740+00   0.000
  49       19.00        0.000    0.000     2.134-01  0.000      5.544+00  0.000    0.000       0.000     6.465-01   0.000
                        4.918-02 0.000     2.963-06  0.000      0.000                               8.924+00   8.100+00   0.000
  50       19.00        0.000    0.000     2.249-01  0.000      1.047+00  0.000    0.000       0.000     4.596-01   0.000
                        5.162-02 0.000     3.115-07  0.000      0.000                               8.686+00   7.577+00   0.000
  51       19.00        0.000    0.000     2.400-01  0.000      2.100+00  0.000    0.000       0.000     4.700-01   0.000
                        5.300-02 0.000     0.000     0.000      0.000                               5.308+00   7.577+00   0.000
  52       25.00        0.000    0.000     1.400-01  0.000      8.094-01  0.000    0.000       0.000     3.700-01   0.000
                        1.000-02 0.000     5.346-20  0.000      0.000                               8.255+00   2.147+01   0.000
  53       25.00        0.000    0.000     1.400-01  0.000      9.000-01  0.000    0.000       0.000     3.700-01   0.000
                        1.200-02 0.000     0.000     0.000      0.000                               9.200+00   2.147+01   0.000
  54       26.00        0.000    0.000     4.100-01  0.000      3.167+00  0.000    0.000       0.000     3.500-01   0.000
                        1.000-02 0.000     2.191-14  0.000      0.000                               8.051+00   9.677+00   0.000
  55       26.00        0.000    0.000     4.100-01  0.000      3.663+00  0.000    0.000       0.000     3.500-01   0.000
                        1.000-02 0.000     1.009-19  0.000      0.000                               8.805+00   1.779+01   0.000
  56       26.00        0.000    0.000     4.100-01  0.000      4.100+00  0.000    0.000       0.000     3.500-01   0.000
                        1.000-02 0.000     0.000     0.000      0.000                               1.560+01   1.779+01   0.000
  57       23.00        0.000    0.000     2.171-01  0.000      2.975+00  0.000    0.000       0.000     1.676-01   0.000
                        6.202-03 0.000     1.599-04  0.000      0.000                               8.473+00   1.341+01   0.000
  58       23.00        0.000    0.000     2.160-01  0.000      3.225+00  0.000    0.000       0.000     1.666-01   0.000
                        6.170-03 0.000     3.057-05  0.000      0.000                               8.488+00   2.451+01   0.000
  59       23.00        0.000    0.000     2.146-01  0.000      3.507+00  0.000    0.000       0.000     1.656-01   0.000
                        6.132-03 0.000     7.170-06  0.000      0.000                               8.636+00   2.375+01   0.000
  60       23.00        0.000    0.000     3.500-01  0.000      3.145+00  0.000    0.000       0.000     2.700-01   0.000
                        1.000-02 0.000     4.156-06  0.000      0.000                               8.483+00   2.391+01   0.000
```

FIGURE B-15. (continued)

```
         EXPLORE I  VERIFICATION ON WILLAMETTE FROM SALEM TO PORTLAND SEPT 67      3      BATTELLE NORTHWEST, RICHLAND, WASHINGTON
                                                                                          EXPLORE-1 CODE QUALITY MODEL
                          DAY   13  HOUR  -.50                           TIDAL CYCLE   12 QUALITY CYCLE   12
  NODE      TEMP.( C )         BEN BOD  SFD PHOS  SOL PHOS  ORG PHOS  CAR BOD   NIT BOD   REF OC       TOC       NH3       NO2
  ****************************************************************************************************************************
                                 NO3      ORG N     TOXIC     PHYTO      ZOO                                   DO        REA       P-R
                               ****************************************************                  ******************************
   61          23.00           0.000     0.000    3.500-01  0.000     3.413+00  0.000     0.000     0.000     2.700-01  0.000
                               1.000-02  0.000    3.562-07  0.000     0.000                                  8.482+00  2.069+01  0.000
   62          23.00           0.000     0.000    3.500-01  0.000     3.702+00  0.000     0.000     0.000     2.700-01  0.000
                               1.000-02  0.000    1.139-08  0.000     0.000                                  8.548+00  1.900+01  0.000
   63          23.00           0.000     0.000    3.500-01  0.000     4.000+00  0.000     0.000     0.000     2.700-01  0.000
                               1.000-02  0.000    0.000     0.000     0.000                                  1.000+01  1.900+01  0.000
```

FIGURE B-15. (continued)

RESERVOIR MODEL

Program Operational Sequence

The overall numerical model for reservoirs and thermal impoundments consists of three component computer programs:

- a generalized input program,
- a thermal-hydraulic simulation program, and
- a water quality simulation program.

The separation of the overall numerical model into component programs provides two important advantages: it allows simultaneous reprogramming and development of individual sections and assures facile replacement of any single component by a more accurate, efficient substitute. In general application the programs are used in sequence so that the determinations of one become input for the others.

The input program CLIMA reads a standard set of meteorologic, hydraulic, and hydrologic data for a particular simulation period and prepares a magnetic tape data file which may be used repeatedly as input to the thermal simulation program.

TERMA, the thermal simulation program, determines the vertical temperature profiles and interflow distributions for the entire simulation period. These predictions are required input data for the water quality program.

Reservoir water quality is modeled with the AQUA program which simulates advective-diffusive transport and chemical reactions of the conservative and non-conservative substances being modeled. As in the river and estuary water quality module, sixteen water quality parameters are modeled by the deep reservoir quality module. Figure B-16 is a diagram of the basic information flow between the three programs CLIMA, TERMA, and AQUA.

Program Descriptions

CLIMA. Various kinds of input data must be prepared for modeling specific reservoir sites and their environments. CLIMA, the generalized input program, performs the important function of ordering, organizing, checking and outputting the standard set of data necessary to initiate a thermal-hydraulic or quality simulation.

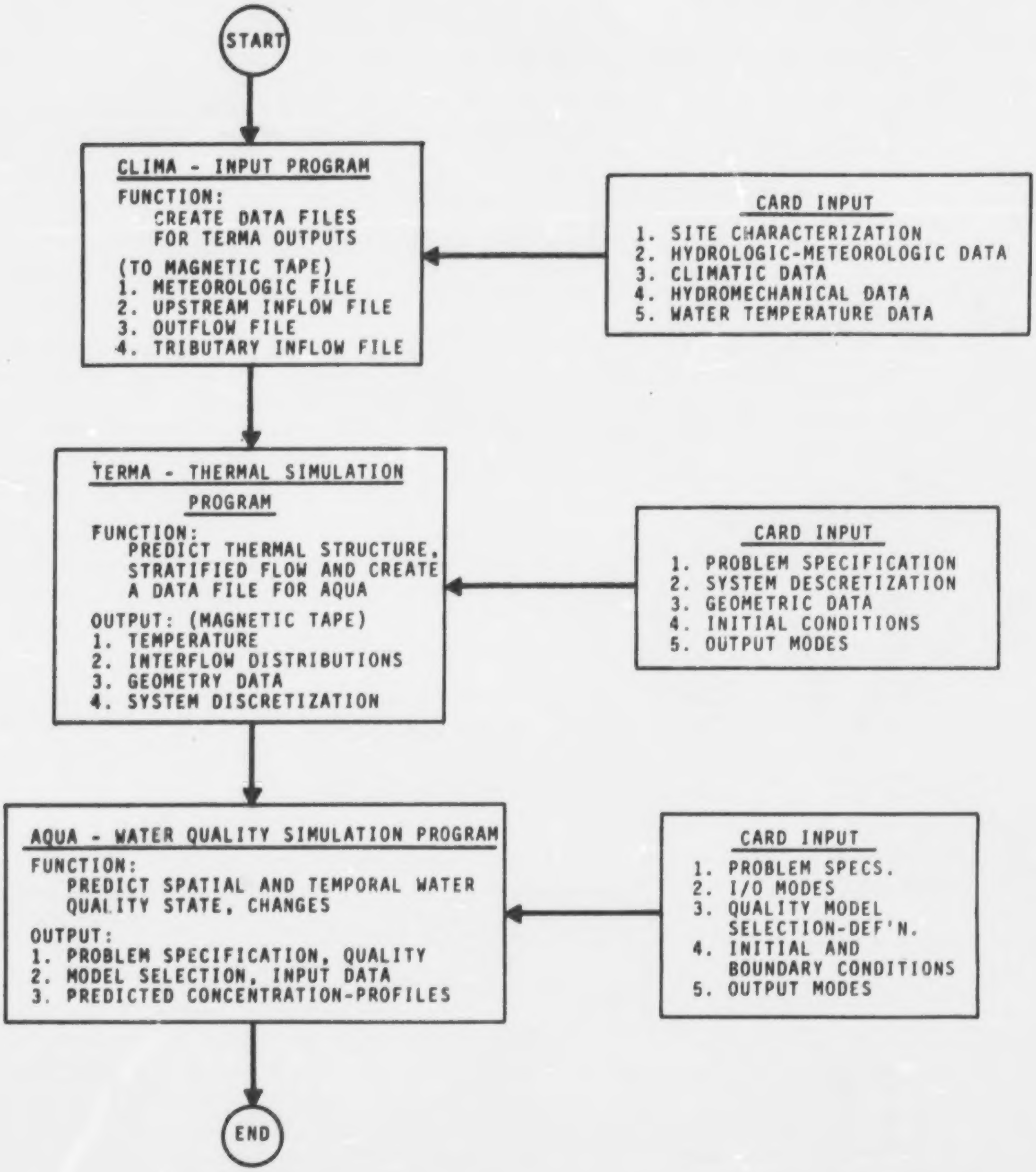

START
CLIMA - INPUT PROGRAM
FUNCTION:
CREATE DATA FILES
FOR TERMA OUTPUTS
(TO MAGNETIC TAPE)
1. METEOROLOGIC FILE
2. UPSTREAM INFLOW FILE
3. OUTFLOW FILE
4. TRIBUTARY INFLOW FILE
CARD INPUT
1. SITE CHARACTERIZATION
2. HYDROLOGIC-METEOROLOGIC DATA
3. CLIMATIC DATA
4. HYDROMECHANICAL DATA
5. WATER TEMPERATURE DATA
TERMA - THERMAL SIMULATION PROGRAM
FUNCTION:
PREDICT THERMAL STRUCTURE,
STRATIFIED FLOW AND CREATE
A DATA FILE FOR AQUA
OUTPUT: (MAGNETIC TAPE)
1. TEMPERATURE
2. INTERFLOW DISTRIBUTIONS
3. GEOMETRY DATA
4. SYSTEM DISCRETIZATION
CARD INPUT
1. PROBLEM SPECIFICATION
2. SYSTEM DESCRETIZATION
3. GEOMETRIC DATA
4. INITIAL CONDITIONS
5. OUTPUT MODES
AQUA - WATER QUALITY SIMULATION PROGRAM
FUNCTION:
PREDICT SPATIAL AND TEMPORAL WATER
QUALITY STATE, CHANGES
OUTPUT:
1. PROBLEM SPECIFICATION, QUALITY
2. MODEL SELECTION, INPUT DATA
3. PREDICTED CONCENTRATION-PROFILES
CARD INPUT
1. PROBLEM SPECS.
2. I/O MODES
3. QUALITY MODEL
SELECTION-DEF'N.
4. INITIAL AND
BOUNDARY CONDITIONS
5. OUTPUT MODES
END

FIGURE B-16. RESERVOIR INTERFACE AND PROGRAM INFORMATION FLOW

Apart from basic data preparation, the primary function of this program is estimation of the net energy flux passing the air-water interface and the equilibrium water surface termperature; these quantities establish boundary conditions for the thermal simulation program.

The computer program consists of five main routines, along with other component subroutines, which prepare selective data according to data group or sub-group:

Group I

Simulation specification and site characterization

1) Period of simulation, days
2) Latitude
3) Longitude
4) Average water surface elevation

Meteorologic-climatic data

1) Number of observations per day
2) Evaporation
3) Atmospheric pressure
4) Sky cover
5) Wind speed
6) Dry and wet bulb temperatures
7) Dew point temperatures
8) Short wave radiation
9) Relative humidity

Group II

Hydrologic data

1) Water surface elevations

2) Upstream inflow rates and temperatures

3) Outflow rates from reservoir

4) Tributary inflow rates and temperatures

General card input is structured to accommodate any units; conversion factors may be input by the user. A complete data echo initializes all printer output, listing all card images (numbered according to group) loaded for program execution. A generalized line printer routine is incorporated in the program to plot the time varying input data. These plots also aid in detecting random errors (such as keypunch errors or systematic inconsistencies in the original data).

TERMA. The TERMA program performs the component function of simulating the thermal-hydraulic behavior of a thermally stratified reservoir. Vertical temperature profiles and interflow distributions are computed for the specified simulation period in days. The thermal simulation program operates on a simple segment-element discretization. A complete reservoir system is represented by N segments, each composed of M horizontal elements (layers). The entire system is simulated segment by segment, working downstream. This successive simulation procedure yields a quasi two-dimensional representation of the reservoir in the form of a series of one-dimensional vertical profiles.

Time step selection for all simulations is the critical factor in program functionality and must be consistent with the input data time base (e.g., data - hourly → simulation step - hourly, data - daily average → simulation step - 1 day, etc.).

Basic card input to the thermal simulation program consists of two main groups and includes:

Group I

Simulation specifications

1) Period of simulations, days

2) Initial and final water surface elevation

3) Heat transfer coefficients

4) Gradient range

5) System discretization

6) Location of tributary inflows

Group II

Segment parameters

1) Elevation - depth profile

2) Segment lengths

3) Initial temperature profile

4) Element thickness

5) Diffusion coefficients

6) Output modes

All printer output is preceded by a complete listing of input card images and is numbered according to group.

AQUA. The AQUA program's primary function is prediction of the quality states of a reservoir site. The program basically solves the water reactions (water quality models) and mass transport equations for the equilibrium concentrations at the end of each time step.

Card input to the AQUA program is necessarily complex due to the variety of input modes (e.g., constant, variable, uniform, etc.) and the nebulous nature of the empirical-experimental coefficients used in the quality models. One standard data group is required for each simulation consisting of:

Group I

Site characterization - specifications

1) Simulation period

2) Reservoir discretization

3) Simulation mode (i.e., with or without water reactions)

4) Quality model selection

5) Rate constants

6) Initial and boundary conditions

7) Output modes

A detailed description of card input structure is presented in the following section.

Preparation of Input Data

Card input modes CLIMA, TERMA, and AQUA have been designed for ease of use. All program listings identify and define the necessary card input and include descriptions of the input variables, appropriate units, and suggested and/or default coefficient values.

Inherent in the overall reservoir model is the use of certain empirical coefficients which attempt to lump complex phenomena into simple mathematical characterizations. The specific values assigned to these coefficients are very important to the correct operation and accuracy of the model components. The computer programs are presently designed to default to a 'workable set' of coefficients. However, calibration of the model to specific reservoir sites requires 'workable ranges' for these coefficients in order to obtain good spatial and temporal correlation between predicted and observed data; Table B-9 presents suggested ranges for most of the coefficients used in the model.

The formal card input structure for each component program of the reservoir model is presented in Tables B-10, B-11 and B-12.

Data Sources

Input data for all three component programs are available from five major sources according to the data category (meteorology, hydraulics, hydrology or quality).

Some reservoirs routinely collect on site daily meteorologic data such as air temperature, water surface temperature, evaporation, wind speed, and relative humidity; however, in most cases, meteorologic data recorded at the nearest weather station must be used. Most of the meteorologic data may be obtained from the National Weather Records Center, Ashville, North Carolina; tabular or punched card form may be requested.

The required hydraulic data consists of the reservoir outflow regulation policy and the observed pool elevations. This data is routinely collected and recorded by the Corps of Engineers.

TABLE B-9

COEFFICIENT RANGES

PROGRAM	COEFFICIENT RANGE	COEFFICIENT DESCRIPTION	UNITS	SOURCE
CLIMA	$0.0 \le A \le 10^{-9}$	Evaporation Coeff. 1	m/mb-sec	EPA(1)
TERMA	$10^{-7} \le B \le 10^{-9}$	Evaporation Coeff. 2	mb^{-1}	BNW,EPA(1)
TERMA	$10^{-5} \le A1 \le 10^{-3}$	Diffusion Coeff. 1	m^2/sec	BNW,WRE(2)
	$10^{-4} \le A2 \le 10^{-3}$	Diffusion Coeff. 2	m^2/sec	BNW
	$0.0 \le A3 \le 1.0$	Diffusion Coeff. 3	-	BNW,WRE(2)
	$.3 \le EXCO \le .6$	Extinction Coef. i.e. short wave extinct. depth: $10 \le EDMAX \le 20$	m^{-1} m	BNW,WRE(1)
	$5 \le GMAX \le 50$	Maximum thermal gradient	°C/m	BNW
	$-1.0 \le GMIN \le 10^{-9}$	Minimum thermal gradient	°C/m	BNW
AQUA	$10^{-5} \le DIFUSY \le 10^{-3}$	Diffusion Coeff.	m^2/sec	BNW

TABLE B-10

CARD INPUT FOR CLIMA

Card No.	Format	Card Columns	Description	Variable Name	Default Value
GROUP I - SITE CHARACTERIZATION AND METEOROLOGY					
1	16A5	1-80	Title	TITLE	NONE
2	5I10	1-10	Year of the meteorologic observations	IYR	NONE
		11-20	First Julian day for simulation	IDAY	NONE
		21-30	Final Julian day for simulation	LDAY	NONE
		31-40	Number of meteorologic observations per day	NOBS	NONE
		41-50	Tape no. for data file output	ITAPE	0
3	5E10.0	1-10	Evaporation coefficient No. 1	A	0.0
		11-20	Evaporation coefficient No. 2	B	1.E-10
		21-30	Latitude of reservoir site	LAT	NONE
		31-40	Longitude of reservoir site	LONG	NONE
		41-50	Average water surface elevation	RESEL	NONE
(NOTE: A minimum of 4 sets of card 4-5 groups are required)					
4	I10	1-10	Code identifying meteorologic parameter to be put in next (0 or 8 terminates Group I input)	ID	NONE
	3E10.0	11-20	Conversion factor 1	CV	1.0
		21-30	Conversion factor 2 $\Big\}$ $X_{ID}=CV*(X_{ID}^{raw} + CVA)+CVB$	CVA	0.0
		31-40	Conversion factor 3 X_{ID}-meteorologic parameter	CVB	0.0
	I5	41-45	Switch for inputting constant or variable meteorologic data values (0→constant, else→variable)	LOGIC	0

TABLE B-10. (continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
5	8E10.0	1-80	Data set for the meteorologic parameter designated in ID code in card 4:	DATA	NONE
		.	1 - atmospheric pressure (mb), 2 - sky cover (dec)		"
		.	3 - wind speed (m/sec), 4 - dry bulb air temp. (°C)		"
		.	5 - wet bulb temp. (°C), 6 - dew point (°C)		"
		.	7 - short wave solar radiation (kcal/m^2-sec)		"
		1-80	8 - relative humidity (dec)		NONE
6	A5	1-5	Sentry designating end of Group I card input: meteorologic data	END	NONE
GROUP II - HYDRAULIC AND HYDROLOGIC INPUT					
1	3I5	1-5	First Julian day with hydraulic and hydrologic data	IDAY	NONE
		6-10	Last Julian day with hydraulic and hydrologic data	LDAY	NONE
		11-15	Blank		NONE
	4E10.0	16-25	Units conversion factor 1 units → m	A1	1.0
		26-35	Units conversion factor 2 units → cms	B1	1.0
		36-45	Units conversion factor 3 units → °C	C1	1.0
		46-55	Units conversion factor 4 units → °C	C2	0.0
2	3E10.0	1-10	Average daily water surface elevations	TA	NONE
		11-20	Average daily upstream inflow rates	TB	NONE
		21-30	Average daily upstream inflow temperatures	TC	NONE
3	3I5	1-5	First Julian day with outflow (discrete withdrawals)	IDAY	NONE
		6-10	Last Julian day with outflow (discrete withdrawals)	LDAY	NONE
		11-15	Number of outlets with withdrawals	NOUTS	NONE

TABLE B-10. (continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
	3E10.0	16-25	Units conversion factor 1 } units → m	A1	1.0
		26-35	Units conversion factor 2 } units → m	B1	1.0
		36-45	Units conversion factor 3 } units → cms	C1	1.0
4	2E10.0	1-10	Elevation of the outflow	ELOUT	NONE
		11-20	Width of dam at elevation of outlet	WOT	NONE
5	8E10.0	1-80	Average daily outflow rates	QOT	NONE
		.			
		.			
		1-80			
6	3I5	1-5	First Julian day of tributary inflow	IDAY	NONE
		6-10	Last Julian day of tributary inflow	LDAY	NONE
		11-15	Number of tributaries with significant inflows	NTRIB	NONE
	3E10.0	16-25	Conversion factor 1 } units → cms	A1	1.0
		26-35	Conversion factor 2 } units → °C	B1	1.0
		36-45	Conversion factor 3 } units → °C	B2	0.0
7	2E10.0	1-10	Average daily tributary inflow rate	QIN	NONE
		11-20	Average daily tributary inflow temperature	TIN	NONE
8	A5	1-5	Sentry designating the end of Group II card input: hydraulic-hydrologic data	END	NONE

TABLE B-11

CARD INPUT FOR TERMA

Card No.	Format	Card Columns	Description	Variable Name	Default Value
GROUP I					
1-2	16A5	1-80	Title or comment identifying the simulation	CMENT	NONE
3	2I10	1-10	First Julian day in the simulation period	IDAY	NONE
		11-20	Last Julian day in the simulation period	LDAY	NONE
4	3E10.0	1-10	Segment element thickness	UDZ	NONE
		11-20	Initial reservoir water surface elevation	ELRES	NONE
		21-30	Maximum reservoir water surface elevation	ELMAX	NONE
5	5E10.0	1-10	Depth of short wave extinction	EDMAX	NONE
		11-20	Evaporation rate coefficient 1	A	0.0
		21-30	Evaporation rate coefficient 2	BB	1.E-9
		31-40	Maximum thermal gradient allowed	GMAX	NONE
		41-50	Minimum thermal gradient allowed	GMIN	NONE
6	8I10	1-10	Total number of tributary inflows	NTRIBS	NONE
		11-60	Segment numbers with tributary inflows	ITRIBS	NONE
		61-70	Number of the segment with outflows	NLETS	NONE
		71-80	Number of reservoir system outlets	NOUTS	NONE
7	A5	1-5	Sentry designating end of Group I card input	END	NONE
GROUP II (NOTE: This data group is repeated for each reservoir segment)					
1	8I10	1-10	Segment number	NSEG	NONE
		11-20	Number of parts in segment area profile	NAP	NONE
		21-30	Number of parts in segment temperature profile	NTP	NONE
		31-40	Number of days for which printed output is requested	NSD	NONE
		41-50	Time print interval	IPRT	NONE
		51-60	Print interval for vertical elements	INTP	NONE
		61-70	Flag for output of temperature to tape (>0)	ITAPE	NONE
		71-80	Flag for output temperature and flow predictions for quality program	NTAPE	NONE

TABLE B-11 (continued)

Card No.	Format	Card Columns	Description	Variable Name	Default Value
2	2I10	1-10	Number of executions per simulation day	NXEQ	1.0
		11-20	Simulation interval in a day with output	IVAL	1.0
3	6E10.0	1-10	Critical stability parameter	GSWH	1.E-6
		11-20	Hypolimnion diffusion coefficient	A1	1.E-3
		21-30	Epilimnion diffusion coefficient 1	A2	1.0E-9
		31-40	Epilimnion diffusion coefficient 2	A3	0.0
		41-50	Vertical thickness of standard element	SDZ	
		51-60	Horizontal segment length	RLEN	NONE
4	2E10.0	1-10	Elevation at which area is specified	TA	NONE
		11-20	Horizontal surface area	TB	NONE
		.			
		.			
		1-10			
		11-20			
5	3E10.0	1-10	Elevation at which initial temperature is specified	TA	NONE
		11-20	Initial temperature at this elevation	TB	NONE
		21-30	Initial time rate of change of temperature	TC	NONE
6	16I5	1-5	Julian day numbers with printed output (up to 50 days) (NSD > 0)	IDOUT	NONE
		6-10			
		.			
		.			
		76-80			
7	A5	1-5	Sentry designating end of Group II card input	END	NONE

TABLE B-12

CARD INPUT FOR AQUA

CARD NO.	FORMAT	CARD COLUMN	DESCRIPTION	VARIABLE NAME	DEFAULT VALUE
			PROBLEM SPECIFICATION		
1-2	16A5	1-80	Comment cards or label	TITLE	None
		1-80	identifying the simulation		
3	8I5	1-5	First Julian day of simulation	IDAY	None
		6-10	Final Julian day of simulation	LDAY	"
		11-15	Switch for selecting transport only (>0)	LOGIC	"
		16-20	Time print frequency (hours)	IPRINT	"
		21-25	Space print frequency (elements)	NPRINT	"
		26-30	Tape No. W/ thermal and hydraulic input	NTAPE1	4
		31-35	Tape No. W/ upstream inflow concentrations	NTAPE2	"
		36-40	Tape No. for quality output	NTAPE3	None
4	2I5	1-5	Number of elements for this reservoir	NELEM 1	None
		6-10		NADA	None
	4E10.0	11-20	Effective diffusion coefficient	DIFUSY	1.E-3
		21-30	Time step for quality simulation (hours)	DELTH	.50
		31-40	Standard element thickness (meters)	DELZ	.50
		41-50	Light extinction depth (Secchi Disk reading)	DEPTH	10.0
			QUALITY MODEL SELECTION		
5	5I5	1-5	Algae model selection (=1,2)	MODALG	2
		6-10	B.O.D. model selection (=1,2)	MODBOD	2
		11-15	D.O. model selection (=1,2,3)	MODDOX	3
		16-20	Nitorgen model selection (=1,2)	MODTIN	2
		21-25	Phosphorus model selection (=1,2,3)	MODPHO	3

TABLE B-12. (continued)

CARD NO.	FORMAT	CARD COLUMN	DESCRIPTION	VARIABLE NAME	DEFAULT VALUE
			QUALITY MODEL COEFFICIENTS		
		(Note:	Eight sets of Card 6 - Card 7 groups are required)		
6	2I5	1-5	Parameter identification (see below)	ID	None
		6-10	Switch for constant for each segment ID code: 1→Algae, 2→B.O.D. 3→Benthic B.O.D., 4→Phosphorus 5→Nitrogen, 6→Suspended Algae 7→T.O.C., 8→Toxic Compounds 0→Sentry for end of coefficient input cards.	SWITCH	None
7	8E10.0	1-80 . . .	Quality model coefficients, coefficient set corresponding to ID	COEF	1.0
		1-80	(see Table B-4 for suggested values)		
			INITIAL CONDITIONS		
		(Note:	A minimum of 1 set of Card 8 - Card 9 groups required)		
8	16I5	1-5	Switch selecting mode of input (SWITCH<0→ constant (no vertical variation for the kth parameter) SWITCH>0→variable data	MODE	None
		6-15	Constant parameter value (if SWITCH<0)	SEGMTS	None

TABLE B-12 (continued)

CARD NO.	FORMAT	CARD COLUMN	DESCRIPTION	VARIABLE NAME	DEFAULT VALUE
9	8E10.0		Initial concentrations for each parameter. J - element index, K - concentration index.	C(1,K)	None
		•	input order:	C(1,K)	None
		1-10	i) Benthic B.O.D. (g/m^2)	1	"
		•	ii) Sedimentary Phosphorus (mg/ℓ)	2	"
		•	iii) Soluble Phosphorous (mg/ℓ)	3	"
		•	iv) Organic Phosphorous (mg/ℓ)	4	"
		•	v) Carbonaceous B.O.D. (mg/ℓ)	5	"
		•	vi) Nitrogenous B.O.D. (mg/ℓ)	6	"
		•	vii) Refractory Organic Carbon (mg/ℓ)	7	"
		1-80	viii) Total Organic Carbon (mg/ℓ)	8	"
		1-10	ix) Ammonia Nitrogen (mg/ℓ)	9	"
		•	x) Nitrite Nitrogen (mg/ℓ)	10	"
		•	xi) Nitrate Nitrogen (mg/ℓ)	11	"
		•	xii) Organic Nitrogen (mg/ℓ)	12	"
		•	xiii) Toxic Compound (mg/ℓ)	13	"
		•	xiv) Phytoplankton (mg/ℓ)	14	"
		•	xv) Zooplankton (mg/ℓ)	15	"
		1-80	xvi) Dissolved Oxygen (mg/ℓ)	16	None
			UPSTREAM INFLOW CONCENTRATIONS		
10	I5	1-5	Index of lowest element with upstream inflow	LOWEST	None
	(Note: A set of 14 cards is required - one card for each parameter)				
11	E10.0	1-10	Upstream inflow concentrations (input order is: Soluble Phosphorus, Organic Phosphorous, ..., Dissolved Oxygen (see CARD 9)	CONC	None

TABLE B-12 (continued)

CARD NO.	FORMAT	CARD COLUMN	DESCRIPTION	VARIABLE NAME	DEFAULT VALUE
			TRIBUTARY INFLOW CONCENTRATIONS		
12	16I5	1-5	Total number of segments w/tributary inflows	NRD	
		6-10 11-15 . . . 76-80	Segment number designations with Tributary inflows	NTRIBS	
13	7E10.0	1-10	Tributary inflow concentrations (input order same as Card 11)	CTRIB	None
14	A5	1-5	Sentry designating end of input deck.	END	None

Hydrologic and quality data for a reservoir may be obtained from various state and Federal agency publications (e.g., state water quality offices, U.S.G.S. Water Supply Papers, state river basin surveys, and E.P.A. STORET data files).

Sample Problem

A sample problem is presented in Tables B-13 through B-15 to demonstrate input card presentation for reservoir simulations. This simulation of the Detroit Reservoir geometry was performed using hypothetical meteorologic, temperature, flow, and quality data. Sample results of this work are presented in Section VIII of the main report.

TABLE B-13

CARD INPUT FOR SAMPLE PROBLEM - CLIMA RUN

```
PREPARE METEOROLOGIC AND HYDROLOGIC DATA FOR 'TERMA' SIMULATION OF DETROIT R.
   2000          1        30          1          4
  0.0        1.E-9    45.       120.       100.0
     1                                       1      ATMOSPHERIC PRESS. (MB)
 1000.0
     2                                       1      SKY COVER (DEC. FRAC.)
  .001
     3                                       1      WIND SPEED (M./SEC.)
  10.0
     4                                       1      DRY.BULB AIR TEMP ( C )
  20.0
     5                                       1      WET BULB AIR TEMP ( C )
  18.0
     6                                       1      DEW POINT TEMP. ( C )
  6.0
     7                                       1      S. WAVE RAD. (KCAL/M**2-SEC)
 .01
     8                                       1      REL. HUMID. (DEC. FRAC.)
END  -GROUP I - METEOROLOGY DATA - FUNCTIONAL TEST.
   1   30
  100.0      10.0      10.0
  100.0      10.0      10.2
  100.0      10.0      10.4
  100.0      10.0      10.6
  100.0      10.0      10.8
  100.0      10.0      11.0
  100.0      10.0      11.2
  100.0      10.0      11.4
  100.0      10.0      11.6
  100.0      10.0      11.8
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
  100.0      10.0      12.0
   1   30    1
                  10.0      100.0      10.0      10.0      10.0      10.0      10.0      10.0
                  10.0      10.0       10.0      10.0      10.0      10.0      10.0      10.0
                  10.0      10.0       10.0      10.0      10.0      10.0      10.0      10.0
                  10.0      10.0       10.0      10.0      10.0      10.0      10.0      10.0
                  10.0      10.0       10.0
                   1   30    0
                END  - GROUP II - HYDRAULICS
```

TABLE B-14

CARD INPUT FOR SAMPLE PROBLEM - TERMA RUN

```
     TRIAL RUN TO DEMONSTRATE THE COUPLING BETWEEN 'TERMA' AND 'AQUA'
     THIS RUN WILL CREATE A DATA FILE: TEMPERATURE AND HYDRAULICS, FOR 'AQUA'
          1         30
      1.0        100.       100.
     20.0        0.0        1.0E-9   500.0    -.01
          0         0         0         0         0         0         1         1
END  -  GROUP I INPUT DATA
          1         92        2         2         5         1         0         7
          1         1
     -1.0E-5   1.0E-3    1.0E-2    0.0       1.0     10000.0
     0.       612166.                                                   ELEV-S. AREA     1
     1.       677973.                                                   ELEV-S. AREA     2
     2.       745598.                                                   ELEV-S. AREA     3
     3.       815047.                                                   ELEV-S. AREA     4
     4.       886316.                                                   ELEV-S. AREA     5
     5.       959404.                                                   ELEV-S. AREA     6
     6.      1034318.                                                   ELEV-S. AREA     7
     7.      1111051.                                                   ELEV-S. AREA     8
     8.      1189605.                                                   ELEV-S. AREA     9
     9.      1269980.                                                   ELEV-S. AREA    10
    10.      1352176.                                                   ELEV-S. AREA    11
    11.      1436193.                                                   ELEV-S. AREA    12
    12.      1522033.                                                   ELEV-S. AREA    13
    13.      1609693.                                                   ELEV-S. AREA    14
    14.      1699174.                                                   ELEV-S. AREA    15
    15.      1790477.                                                   ELEV-S. AREA    16
    16.      1883600.                                                   ELEV-S. AREA    17
    17.      1978547.                                                   ELEV-S. AREA    18
    18.      2075314.                                                   ELEV-S. AREA    19
    19.      2173900.                                                   ELEV-S. AREA    20
    20.      2274311                                                    ELEV-S. AREA    21
    21.      2376539.                                                   ELEV-S. AREA    22
    22.      2480590.                                                   ELEV-S. AREA    23
    23.      2586465.                                                   ELEV-S. AREA    24
    24.      2694158.                                                   ELEV-S. AREA    25
    25.      2803676.                                                   ELEV-S. AREA    26
    26.      2915010.                                                   ELEV-S. AREA    27
    27.      3028166.                                                   ELEV-S. AREA    28
    28.      3143146.                                                   ELEV-S. AREA    29
    29.      3259945.                                                   ELEV-S. AREA    30
    30.      3378568.                                                   ELEV-S. AREA    31
    31.      3499010.                                                   ELEV-S. AREA    32
    32.      3621271.                                                   ELEV-S. AREA    33
    33.      3745359.                                                   ELEV-S. AREA    34
    34.      3871266.                                                   ELEV-S. AREA    35
    35.      3998994.                                                   ELEV-S. AREA    36
    36.      4128541.                                                   ELEV-S. AREA    37
    37.      4259910.                                                   ELEV-S. AREA    38
    38.      4393103.                                                   ELEV-S. AREA    39
    39.      4528113.                                                   ELEV-S. AREA    40
    40.    . 4664949.                                                   ELEV-S. AREA    41
                                                     -  -  -  -  -  -  -  -
    41.      4803604.   ELEV-S. AREA      42
    42.      4944078.   ELEV-S. AREA      43
    43.      5086379.   ELEV-S. AREA      44
    44.      5230494.   ELEV-S. AREA      45
    45.      5376437.   ELEV-S. AREA      46
    46.      5524195.   ELEV-S. AREA      47
    47.      5673777.   ELEV-S. AREA      48
    48.      5825184.   ELEV-S. AREA      49
    49.      5978406.   ELEV-S. AREA      50
    50.      6133455.   ELEV-S. AREA      51
    51.      6290320.   ELEV-S. AREA      52
    52.      6449008.   ELEV-S. AREA      53
    53.      6609519.   ELEV-S. AREA      54
    54.      6771850.   ELEV-S. AREA      55
    55.      6936006.   ELEV-S. AREA      56
    56.      7101977.   ELEV-S. AREA      57
    57.      7269769.   ELEV-S. AREA      58
    58.      7439387.   ELEV-S. AREA      59
    59.      7610824.   ELEV-S. AREA      60
    60.      7784084.   ELEV-S. AREA      61
    61.      7959162.   ELEV-S. AREA      62
    62.      8136062.   ELEV-S. AREA      63
    63.      8314785.   ELEV-S. AREA      64
    64.      8495328.   ELEV-S. AREA      65
    65.      8677695.   ELEV-S. AREA      66
    66.      8861881.   ELEV-S. AREA      67
    67.      9047885.   ELEV-S. AREA      68
    68.      9235717.   ELEV-S. AREA      69
    69.      9425365.   ELEV-S. AREA      70
    70.      9616838.   ELEV-S. AREA      71
    71.      9810129.   ELEV-S. AREA      72
    72.     10005238.   ELEV-S. AREA      73
    73.     10202178.   ELEV-S. AREA      74
    74.     10400930.   ELEV-S. AREA      75
    75.     10601510.   ELEV-S. AREA      76
    76.     10803906.   ELEV-S. AREA      77
    77.     11008125.   ELEV-S. AREA      78
    78.     11214168.   ELEV-S AREA       79
    79.     11422027.   ELEV-S. AREA      80
    80.     11631715.   ELEV-S. AREA      81
    81.     11843217.   ELEV-S. AREA      82
    82.     12056541.   ELEV-S. AREA      83
    83.     12271689.   ELEV-S. AREA      84
    84.     12488658.   ELEV-S. AREA      85
    85.     12707449.   ELEV-S. AREA      86
    86.     12928059.   ELEV-S. AREA      87
    87.     13150488.   ELEV-S. AREA      88
    88.     13374744.   ELEV-S. AREA      89
    89.     13600818.   ELEV-S. AREA      90
    90.     13828715.   ELEV-S. AREA      91
   100.     13828715.   ELEV-S. AREA      92
      0.0       10.0        1.0E-9

      100.0     13.0        1.0E-9
      1    30
END  -  GROUP II INPUT DATA
```

TABLE B-15

CARD INPUT FOR SAMPLE PROBLEM - AQUA RUN

```
FUNCTIONAL  TESTING OF RESERVOIR WATER QUALITY SIMULATION CODE.  A SINGLE SEGMENT
 PROBLEM IS SIMULATED WITH TIME VARYING  TEMPERATURE AND HYDRAULICS - RGB
   1   30    0    1    5    4    0    0
  99    1    1.0E-3  24.0        1.0       20.0
   1    2    2    1    1                 QUALITY MODEL SELECTION
   1    0         ALGAL COEF.
  .2        .6        2.        5.        30.       .025      .0025
  .005      .15       .6        60.       .20       .02       .0
  0.0       0.0       0.0
   2    0         B.O.D. COEF.
  .3        0.0       0.0       1.05      1.0
   3    0         BENTHIC COEF.
  .005      1.05
   4    0         PHOSPHOROUS COEF.
  .25
   5    0         NITROGEN COEF.
  .10
   6    0         SUSPENDED ALGAE COEF.
 0.0       0.0       0.0       0.0       0.0
   7    0         T.O.C. COEF.
  0.005     0.9       0.0       0.0       1.0
   8    0         TOXIC COEF.
  0.005     0.8       1.0
   0    0         END OF MODEL COEFF. DATA
  -1  2.0         I.C.      BENTHIC B.O.D.
  -2  .50                   SEDIMENTARY PHOSPHOROUS
  -3  .05                   SOLUBLE PHOSPHOROUS
  -4  .0005                 ORGANIC PHOSPHOROUS
  -5  1.0                   CARBONACEOUS B.O.D.
  -6  0.0                   NITROGENOUS B.O.D.
  -7  .0005                 REFRACTORY ORGANIC CARBON
  -8  .0005                 TOTAL ORGANIC CARBON
  -9  .50                   AMMONIA NITROGEN
 -10  .05                   NITRITE NITROGEN
 -11  .50                   NITRATE NITROGEN
 -12  .0005                 ORGANIC NITROGEN
 -13  0.0                   TOXIC COMPOUND
 -14  5.0                   PHYTOPLANKTON
 -15  .50                   ZOO PLANKTON
  16              END I.C.  DISSOLVED OXYGEN
  11.2711   11.2629   11.2547   11.2465   11.2384   11.2302   11.2220   11.2139
  11.2058   11.1976   11.1895   11.1814   11.1733   11.1652   11.1572   11.1491
  11.1410   11.1330   11.1249   11.1169   11.1089   11.1009   11.0929   11.0849
  11.0769   11.0690   11.0610   11.0531   11.0451   11.0372   11.0293   11.0214
  11.0135   11.0056   10.9977   10.9899   10.9820   10.9741   10.9663   10.9585
  10.9507   10.9429   10.9351   10 9273   10.9195   10.9117   10.9039   10.8962
  10.8885   10.8807   10.8730   10 8653   10.8576   10.8499   10.8422   10.8345
  10.8269   10.8192   10.8116   10.8039   10.7963   10.7887   10.7811   10.7735
  10.7659   10.7583   10.7507   10.7432   10.7356   10.7281   10.7205   10.7130
  10.7055   10.6980   10.6905   10.6830   10.6755   10.66[illegible]   10.6606   10.6531
  10.6457   10.6382   10.6308   10.6234   10.6160   10.6086   10.6012   10.5938
```

TABLE B-15. (Continued)

```
   10.5865   10.5791   10.5718   10.5644   10.5571   10.5498   10.5424   10.5351
   10.5278   10.5206      10.5133
    0              LOWEST ELEMENT WITH INFLOW
  .50              INFLOW    SOLUBLE PHOSPHOROUS
   .005                      ORGANIC PHOSPHOROUS
15.0                         CARBONACEOUS B.O.D.
 0.0                         NITROGENOUS B.O.D.
  .005                       REFRACTORY ORGANIC CARBON
  .005                       TOTAL ORGANIC CARBON
 1.0                         AMMONIA NITROGEN
  .50                        NITRITE NITROGEN
 1.0                         NITRATE NITROGEN
  .005                       ORGANIC NITROGEN
 5.0                         TOXIC COMPOUND
 5.0                         PHYTOPLANKTON
 1.0                         ZOO PLANKTON
10.0               END       DISSOLVED OXYGEN
    0    0         TRIBUTARY INFLOW - DEFAULT
END      FUNCTIONAL TESTING OF THE RESERVOIR QUALITY SIMULATION PROGRAM
```

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B-5. Water Resources Engineers, "Mathematical Models for the Prediction of Thermal Energy Changes in Impoundments." Prepared for EPA December 1969.

B-6. Water Resources Engineers, "Prediction of Thermal Energy Distribution in Streams and Reservoirs." Prepared for the Department of Fish and Game, State of California, Revised August 30, 1968.

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